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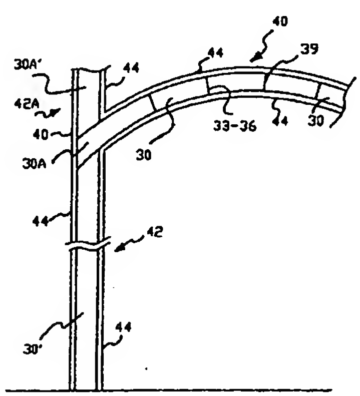
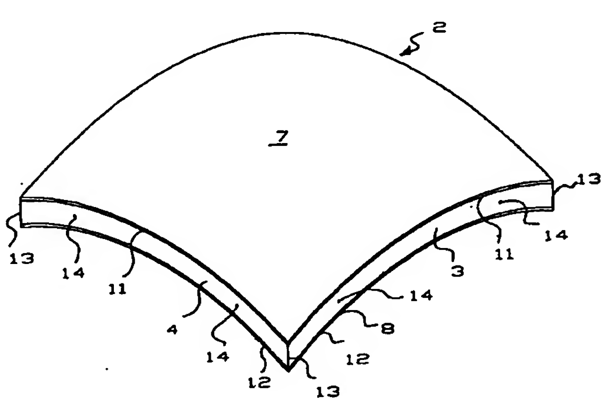
(54) Title: METHOD OF CONSTRUCTING CURVED STRUCTURES AS PART OF A HABITABLE BUILDING





(57) Abstract: Flat, transparent or opaque plastic sheets are used to build curved structures (1) that form portions of habitable buildings. The curved structure (1) is divided into sections (2) using a Computer Assisted Drafting program. The plastic sheets are cut into sides (3-6) and top and bottom panels (7, 8) by a Computer Assisted Manufacturing machine. The sides (3-6) are joined to form a frame (9). The sides (3-6) have curved upper and lower edges (11, 12) that match the curvature of the structure (1). The top and bottom panels (7, 8) are placed on the frame (9) formed from the sides (3-6) and bent to match the curvature of the sides. The panels (7, 8) are joined to the sides. The sections (2) are joined together to form the curved surface (1). In another mode, foam blocks (30) are used to build curved structures. The foam blocks (30) are cut to the curvature of the curved structure (1) by a Computer Assisted Manufacturing machine. The blocks are joined and then coated with a high strength coatin (44).

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Method of Constructing Curved Structures as Part of A Habitable Building

Technical Field

The present invention relates to habitable buildings commonly used for homes, offices, and other purposes.

More particularly, this invention relates to habitable enclosures having portions of the enclosure that is curved structures.

In a further and more specific aspect, the invention concerns a method of building curved transparent and opaque structures of great strength and low cost from materials in commercially available sizes.

Background Art

The majority of new buildings today rely on the old methods that use bearing walls or columns to support a heavy roof or an intermediate floor. Structures built in this way are susceptible to forces caused by gravity, adverse weather and earthquakes. The stresses in the buildings induced by these forces can cause cracks in and eventually the failure of the building. Internal stresses at the corners and joints of such buildings are amplified by the construction methods. Failure of such buildings is initiated at their weakest points.

Conventional structures use massive quantities of materials and require excessive amounts of labor time and energy to construct. Forests are cut down to provide the lumber. Energy is expended to mine and create metal beams and components, which carry the weight of the other building materials. Furthermore, a great

amount of human, machine and combustible fuel energy is needed to transport and assemble the materials at job site.

Architects are designing buildings that are pleasing to the eye but are expensive to build. The buildings have curved surfaces, which are very expensive to construct.

There has been a need for a method of creating a structure, such as a home, a vault for a mall, a sports stadium, etc. from less expensive materials and labor and a need for a method of building the structures more quickly.

Further, there has been a need for creating buildings that are more resistant to the forces of nature.

It would be highly advantageous, therefore, to remedy the foregoing and other deficiencies inherent in the prior art.

Accordingly, it is an object of the present invention to provide an inexpensive method of creating structures of considerable strength while creating a building of customary appearance.

Another object is to be able to create structures of arbitrary curvature form inexpensively without the need for a structural skeleton.

A further object is to create structures of high strength out of lightweight materials in commercially available sizes by incorporating curved, dome-like or shell-like structures into the building.

Another object is to provide a transparent structure of considerable strength which could be used to create stadiums, arenas and sport complex roofs.

A further object is to create a fiber or cable reinforced curved structure of very high strength.

Another object is to create an inexpensive method of making transparent structures, such as skylights, domes, vaults and canopies, which is of especial interest in the construction of malls and many other structures.

A further object is to provide a method for creating a virtual structure having curved portions in a computer, then sectioning the structure by the computer program into smaller, more manageable sections, forming the curved sections from flat / planar pieces. The forming step can be accomplished by feeding the data from the computer assisted drafting (CAD) program to a computer assisted machining program (CAM) in a cutting machine.

Another object is to make a 3-D curved structure without the use of expensive forming processes. Before the development of CAD-CAM, such a curved structure would have been very expensive to create.

A further object is to create buildings more quickly.

A further object is to build the structure in portions made from joining sections until the combined sections are of an appropriate size to be raised to form a portion of the structure.

Another object of the invention is to make a structure that is more resistant to the external forces experienced during snow, winds and earthquakes. This is accomplished in two ways. First, the weight of the structure is reduced. Second, the strength of a curved shell is exploited.

Disclosure of Invention

Briefly, to achieve the desired objects of the instant invention in accordance with a preferred embodiment thereof, provided is a computer operated cutting machine (CAM) having a rotating cutting device much like a router that is fed information from the computer generated (virtual) curved structure created by the computer assisted drafting (CAD) program. The CAM cuts curved top and bottom surfaces on pieces that become the sides of a portion of the overall curved structure. The sides are joined to form a frame, and flat top and bottom panels are joined to the curved top and bottom surfaces of the frame. The panels are flexed to conform to the curvature of the top and bottom surfaces during the joining step. The assembled section of the curved structure is joined to other sections to form the curved structure. The sides and panels are plastic preferably are transparent. In another embodiment thereof, provided is a CAM having a hot wire cutter for cutting foam. The CAM is fed information by a CAD computer and cuts the top and bottom surfaces of a foam block. The blocks are joined to create a form which is spray coated to build the overall curved structure.

Brief Description of Drawings

The foregoing and further and more specific objects and advantages of the instant invention will become readily apparent to those skilled in the art from the following detailed description of preferred embodiments thereof, taken in conjunction with the drawings in which:

Figure 1 is a perspective view of the curved structure.

Figure 2 is a perspective view of a rectangular, curved section of the curved structure.

Figure 3 is a perspective view of the four sides of the curved section which create a form or frame.

Figure 4 shows a front view of one of the sides.

Figure 5 shows an exploded view of the pieces making a section with the top and bottom panels being shown as they are before they are bent on to the frame.

Figure 6 is a cross-sectional view of alignment holes in the adjacent sides.

Figure 7 is a front view of an alignment pin.

Figure 8 is a cross-sectional view of joined adjacent sides.

Figure 8A is a cross-sectional view of another embodiment of the joined sides.

Figure 9 is a cross-sectional view of a further embodiment of the joined sides.

Figure 10 is a perspective view of a curved structure formed from triangular sections.

Figure 11 is a perspective view of a triangular section.

Figure 11A is a perspective view of the joined sides of a triangular section.

Figure 12 is an exploded, perspective view of groups of joined panels.

Figure 13 is front view of a curved structure in the form of a vault.

Figure 14 is a side view of a block used in a second, different embodiment of the invention.

Figure 14A is a perspective view of the second embodiment formed from triangular sections.

Figure 14B is an exploded, perspective view of the sections of Figure 14A.

Figures 15A-C are exploded, side views of different embodiments of the joint between adjacent blocks.

Figure 16 is a side view of an assembly of blocks.

Figure 17 is cross-sectional view of a portion of the habitable enclosure.

Figure 17A is a cross-sectional view of another embodiment of a portion of the habitable enclosure.

Figure 18 shows a perspective view of the first floor of one example of a habitable enclosure constructed according to the second embodiment.

Figure 19 shows a perspective view of the ceiling assembly.

Figure 19A shows a section of the ceiling assembly of Figure 19.

Figure 20 shows a perspective view of the ceiling assembly in place on the side walls.

Figure 21 shows a perspective view of the attic side walls added to the enclosure.

Figure 22 shows a perspective view of the roof added to the enclosure.

Mode(s) for Carrying Out the Invention

Figure 1_shows a curved composite structure 1 formed of curved sections 2 having a rectangular form. The curved sections 2 can have a triangular form, a pentagonal form or any other multi-sided form. The curved sections 2 are formed from flat sides 3,4,5,6 and top and bottom flat panels 7 and 8.

Preferably, the materials used in the sides and panels are plastics, such as acrylics, polycarbonates, etc. The plastics can be transparent, translucent, opaque or a combination depending on the requirements of the section. The thickness of the top and bottom panels is typically in the range of one sixteenth to one half of an inch.

In Figure 2, one curved section 2 is shown. The curved section 2 is shown to have a very mild or gentle curvature. Such a curvature is created by a very large radius of curvature. The section 2 is part of a dome structure 1 and is therefore curved in two directions. As is shown more clearly in Figures 2 and 3, the sides 3-6 are formed so that their top and bottom edges are curved. The sides are joined to create a multi-sided form / frame 9 upon which the flat top and bottom panels are bent and secured.

The curved section could be created by just having sides with curved top or bottom edges and top or bottom panels, respectively. When the panel 7or 8 is bent to form a gentle curve, the panel stress level will usually be in the elastic deformation range. Thus, there will be residual stresses in the panel trying to return it to a flat configuration. Those stresses are very low.

Figure 4 shows a side 3 which is used to form the composite curved structure section 2. The side 3 has an upper edge 11 and a lower edge 12. The edges 11 and 12 are formed with a curvature that matches the desired curvature of the section 2 of the composite curved structure 1. The edges 11 and 12 can be formed by removing material 11' and 12' from a straight edged, flat piece of material 3'.

The removal of material can be performed by a computer operated cutting machine (CAM), having a rotating cutting device much like a router, that is fed information from the computer generated (virtual) structure that is created by the computer assisted drafting (CAD) program. The curvature can also be formed by casting the side with the desired curvature in a mold.

Figure 5 shows top panel 7 that is rectangular and similar in shape to the bottom panel 8, only larger. The top and bottom panels 7 and 8 are made from flat / planar elements. In an application as a skylight, the panel is made of transparent or translucent plastic.

The section 2 is formed by joining sides 3,4,5,6 to create a form or frame 9, placing panels 7,8 on the form / frame 9 created by the joined sides, and bending and joining the top and bottom panels 7,8 to the sides 3,4,5,6. Thus, the curvature of the section 2 is created by cutting away material 11' and 12' to form the desired curvature of edges 11,12, by cutting the top and bottom panels 7, 8 to rectangles to match the area of the form or frame 9 defined by the joined sides, by bending the panels 7,8 on to the sides 3-6 to match the curvature of the sides, and by joining the top and / or bottom panels 7,8 to the sides 3-6.

In Figure 2, sides 3,4,5,6 are joined along edges 13 to each other. Top and bottom panels 7 and 8 are bent on and joined to the upper and lower edges 11 and 12. The bending is done during the joining operation. The panels are bent and held in place during the joining operation. The holding in place step can be accomplished by the use of tape, a hold down fixture or jig, tack welds, rivets, etc.

The joining of the sides 3-6 to each other can be performed by using a solvent for the plastic material from which the sides are made.

The joining of the panels 7,8 to the frame 9 created from the sides can be performed by adhesives, welds, mechanical devices such as rivets, etc. One such adhesive is WELD-ON 40TM, a Clear Two-Component, Reactive, High Strength Acrylic Cement used for joining acrylic materials. Another adhesive is a solvent for the plastic material from which the sides and the panels are made. The welding could be performed hot plate welders which apply heat to the areas to be welded.

The joints can be butt joints where the edge 13 of one side abuts the side of another side. Preferably as seen in Figure 3, the side joints can also be made by chamfering the edges 13 at an angle of 45 degrees so that they can be joined to form the 90 degree corner of a rectangle. Of course, different angles of chamfer would be used for different forms of multi-sided sections.

The section 2, when made of clear or translucent materials, can be used by itself or with other sections as a window or skylight. When made of opaque

materials, the section or sections can be used to form other types of curved structures.

The structure of Figure 1 can be created in a computer as a virtual structure by the use of a computer assisted drafting (CAD) program. The structure can be divided by the CAD program into pieces / sections using either Cartesian or polar coordinates. Using Cartesian coordinates, the structure would be divided along X,Y and Z axes. Using polar coordinates, the structure would be divided by lines radiating from a point. The division of the structure into sections allows the structure to be made of planar pieces or sheets in sizes that are commercially available, such as 4x8 feet, 5x10 feet, etc.

The planar sections can be cut by the use of a computer assisted cutting machine (CAM). The data from the CAD program is fed into the CAM which then cuts the planar sections, such as the sides, the top and the bottom panels. The sides have the top and bottom edges cut to the desired curvature. The top and bottom panels are cut to fit the form or frame created by the joined sides. The cut planar pieces can be assembled to form sections in the field or in a factory and then transported to the field. The sections are then assembled to form the structure.

As shown in Figure 2, 3 and 6, the sides 3-6 can have alignment holes 14. Preferably, the aligned holes 14 are formed with a countersunk portion 15. Figure 7 shows a pin 16 having a shoulder 17 which fits into the countersunk portion 15 of the hole to prevent the pin 16 from falling into the inside of section 2. Sections 2 are assembled side by side and aligned by the use of holes 14 and

pins 16. Each side is shown as having two holes 14 to more quickly achieve alignment.

To assemble, the pin 16 is placed in hole 14 until shoulder 17 seats in countersunk portion 15. Then, the abutting section 2 is aligned with aforementioned section by placing the seated pin in the hole of side of the adjacent section. The shoulder 17 need not fit the whole of the countersunk portion 15. Further, both holes 14 need not be countersunk. Further, no countersink would be needed where a pin is bonded in the hole of one side. Of course, other types of alignment devices can be used.

Figure 8 shows two sections 2 assembled side by side / adjacent. Sides 3-6 have an adhesive 18 applied to the top portion by any applicable means such as nozzle, spray, roller, brush or tape. Suitable adhesives are 3M's VHB TM Coated Acrylic Foam Tapes and Adhesive Transfer Tapes (4905-4959 and F4960PC-F4973PC) or 3M's SCOTCH GRIP TM Plastic Adhesives (1099,1099L). The tape applicator would have at least one protective backing to make it easy to handle. The backing is used to lay the adhesive on the sides 3-6, and then the backing is peeled off exposing the adhesive for contact with the adjacent side wall 3-6 or any adhesive applied to the adjacent side.

In the embodiment of Figure 8, the adhesive 18 is placed at the top of area of the sides. The adhesive 18 forms a dam in the space / gap 21 between the adjacent sides 3-6 and panels 7,8. The thickness of the adhesive forms a gap 21, typically of about 0.05 inches, between the edges of the top panel 7 of adjacent sections. Preferably, the adhesive 18 should never fully harden so that it will be prevented from forming a high stress in the sides.

Another adhesive 22 can be placed in the gap 21 created by the dam formed by adhesive 18. Typical adhesives 22 can be WELD ON 40 TM, 3M's VHB

TM Coated Acrylic Foam Tapes, such as 4905 and 4910, or a solvent for the plastic of the side, such as a solvent for acrylics, polycarbonates, etc., which will melt the surface of the plastic of the adjacent surfaces thereby allowing the plastic to flow and bridge the gap where it solidifies.

In another embodiment shown in Figure 8A, only 3M's tapes, 3M's VHB TM Coated Acrylic Foam Tapes and Adhesive Transfer Tapes (4905-4959 and F4960PC-F4973PC), are used. The tape 18 will fill the gap 21 and extend onto the side 3-6, and there will be no need to form a dam since the adhesive on the tapes will not run. During the assembly, the adhesive 18 is placed on the sides before the sides are aligned adjacent to each other. The gap 21 between the top panels can be filled with an adhesive 18 or 22, a caulk or left unfilled or partially filled.

The bottom panels 8 can be united by the same assembly steps. The structure 1 can be created by using either of the top panels, the bottom panels or both.

Figure 9 shows sides 3,4 formed with cavities 23, 24. The cavities 23,24 form a larger cavity which is sealed by the dams created by adhesive 18 which is applied along the top and bottom edges of the cavities 23,24. The cavities 23,24 are filled with a bonding agent 25 which can be the liquid, unset form of the plastic that is used for the side, such as a liquid acrylic if using acrylic sides. The bonding agent may contain fibers, cables or ropes 26 for reinforcement. The fibers, cables or ropes 26 can be made of FIBERGLAS TM, carbon, graphite, etc. The bonding agent 25 reinforced by fibers, cables or ropes is used to increase the strength of the structure 1. The gap 21can be filled with an adhesive 18 or 22, a caulk or left unfilled or partially filled.

Figure 10 shows a curved structure 1 in the shape of a portion of a dome. The dome can be divided into triangular curved sections 2. Only four triangular sections 2 are shown in Figure 10; however, the whole dome is made of curved triangular sections. The sections are similar to the rectangular sections of Figure 1.

Figures 11 and 11A show a section 2 in the triangular form of Figure 10. There are three sides 3-5, preferably equal in length and a top and bottom panel 7,8. The sides 3-5 are formed with curved top and bottom edges 11,12 to match the curve of the dome. The sides 3-5 are joined to create a form or frame 9. The triangular top and bottom panels 7,8 are placed on the form created by the edges 11,12, bent to match the curve of the edges 11,12 and then joined to the edges.

Figure 12 shows two groups A,B of triangular sections 2 that have been joined together by adhesives. The joined groups A,B are joined to each other by placing adhesives 18 on the sides 3-5, then aligning the pins 16 in holes 14 (not shown) and pressing the sides of group A to the sides of group B. Eventually, two halves will be joined by the aforementioned technique to form the dome.

Figure 13 shows a curved structure 1 formed as a vault-like roof for a walkway or other use. In this form, the sections may be curved in only one direction, instead of two as required for a dome. That is, only two opposite sides 3,5 or 4,6 will have their upper and lower edges 12,13 formed to match the desired curvature of the vault.

Figure 14 shows a different embodiment of the overall concept of creating strong, lightweight curved structures. In this embodiment, the rectangular sections 2 are formed from core materials, such as, rectangular, expanded polystyrene solid panels 30'. Rectangular, solid formed panels or blocks 30 have curved upper and lower surfaces 31 and 32 and four tapered sides 33-36. Sides 33 and 35 have a taper that is dictated by the radius of curvature R in a first direction of the curved

structure 1 of which section 2 is a piece. If the structure 1 is curved in first and second directions, sides 34 and 36 will also have a taper dictated by the radius of curvature taken along the second direction. The shape of the panel or block 30 is shown somewhat exaggerated to clearly show the curvature and the taper. In another embodiment (not shown), either the top or the bottom surface of the foam block is left flat and the bottom or the top, respectively, is formed in the desired curve.

The curved rectangular, formed foam block 30 can be formed from a flat-sided block of core material 30' by using a computer assisted cutting machine (CAM) having a rotating cutter much like a router. The procedures to be followed would be similar to those previously discussed. The blocks can also be cut by a device called a hot wire. Another method of forming would cast the rectangular, solid panel 30 with tapered sides and curved upper and lower surfaces. As in the previous embodiment, the blocks or panels 30 can have a triangular form, a pentagonal form or any other multisided form.

Preferably, the blocks 30 would be sized so that they could be cut from core material blocks 30' that are manufactured in commercially available sizes, such as 4x 8 feet, 5x10 feet, etc.

Figure 14A shows the four foam blocks 30 of a triangular form joined together.

Figure 14B shows an exploded view of the four foam triangular blocks with holes 37 and pins 38 for alignment of the blocks.

The blocks 30 are assembled as shown in Figures 12, 14B and 15. The sides 33-36 are affixed to an adjacent block by any suitable means, such as, adhesive, interlocking joints, etc. or combination thereof. The interlocking joint could typically be a tongue and groove design, as shown in Figure 15A, formed on

sides 33-36 of the blocks 30. The blocks 30 can also be aligned by using the tongue and groove interlocking joint or a pin 38 and hole 37 interlocking joint, as shown in Figure 15B, in which the pin 38 of about an inch in diameter fits in holes 37 in adjacent blocks 30. A suitable foam adhesive 39, as shown in Figure 15C, would be 3M FASTBOND TM Foam Adhesive 100 which is a neoprene based product. Preferably, the blocks 30 are joined by using an adhesive and an interlocking joint.

As shown in Figure 16, once the desired number of blocks 30 are assembled, if the span is large, at least one side of the ceiling assembly 40 is coated with a precoat 41 that dries to form a hard, reinforcing shell. Suitable precoat materials 41 for use with polystyrene blocks 30 can be polyurethane or polyurea elastomer coatings. If the span is smaller, the assembly 40 is raised into position without the coating.

Figure 17 shows side walls 42 which are formed by joining 4 foot x 8 foot x 2 - 12 inch foam blocks 30' along their long sides with adhesives, interlocking joints or other joining devices. The side walls 42 are positioned on concrete footings 51 in the trench 50 in the ground. Once the side walls 42 are erected, a cornice 43 or other ceiling support which can be formed from foam blocks is added to the top area of the side wall 42 by foam adhesive 39. The cornice 42 is cut in a curve to follow the curvature of the ceiling where the ceiling meets the side walls 42. The ceiling assembly is joined to the cornice, preferably by foam adhesive 39. The side walls 42 and cornice 43 can be coated with a high strength coating 44 before the ceiling assembly is raised into position on the cornice 43 or ceiling support. However, the use of the high strength coating 44 on the side walls and cornice can usually wait until after the ceiling assembly is raised into place on the cornice.

The high strength coating 44 can be made of a resin having fibers of glass, carbon, etc. or a high performance, fiber reinforced concrete with a polymer additive for accelerated curing. A suitable concrete would be glass fiber reinforced concrete

(GFRC) which can be sprayed on to the previous coating 41 or onto the foam 30. The GFRC is manufactured by THE VEROTEX Company. The GFRC is 3-5% of Cem-FIL TM fibers (glass fibers) that are mixed into a 1:1 cement :sand and water matrix. Preferably, the coating 44 is made from a very thin layer of GFRC, such as 3/16 - 1/2 inches.

Once the ceiling assemblies 40 are in place, the coating 44 can be applied to unite the adjacent assemblies 40 to each other and the assemblies 40 to the side walls 42 and cornice 43 or ceiling support. The top side of the ceiling assembly 40 and the adjacent side walls 42A are also coated with the high strength coating 44. The side walls 42, 42A are also coated inside and outside with coating 44. Once the lower portion of the side walls 42 has been coated, concrete fill 52 can be added to the trench 50.

As shown in Figure 17A, the side wall 42 can be cut to receive the ceiling assembly 40. In this embodiment, the side wall 42 does not need a cornice 43 to support the assembly 40. The outer foam blocks 30A are trimmed by the use of a hot wire to match the side of the side wall 42. The ceiling assembly 40 is joined to the side wall 42 at its top, preferably by foam adhesives 39. A foam block 30A' is formed to fit the curvature of the ceiling block 30A and is joined thereto. Foam block 30A' extends the side wall 42 past the ceiling assembly 40 to form an attic side wall 42A.

Figures 17-22 show an example of a habitable enclosure created by the method of the second embodiment. Figure 18 shows the side walls 42 of a first floor with the high strength coating. Figure 19 shows the uncoated ceiling 40 that is placed on the side walls 42 with one of the triangular sections 2 exploded into Figure 19A. Figure 20 shows the ceiling assembly 40 in place on the side walls 42. The sides 33-35 of sections 2 are trimmed by a hot wire to match the uncoated, side wall 42. Figure 21 shows the attic side walls or strengthening ribs 42A. The ceiling assembly 40 is shown as uncoated to more clearly show its form. Figure 22 shows

the roof 45 added to the side walls 42. All of the exterior surfaces, roof and walls, will be coated to provide additional strength. The ceiling assembly 40 is shown as uncoated on its exterior side as in Figures 20-22 to more clearly show its form where it lays on the first floor side walls 42.

A more detailed and slightly different sequence of building steps follows below. A foundation trench is excavated to a minimum depth deeper than the frost line. A strip footing is made by pouring about six inches of concrete which may be reinforced if desired. The top surface of the strip footing is finished level and smooth to receive 3M TM VHB TM Double Coated Acrylic Foam Adhesive Tape 4910 having removable protective front and back covering layers or backings. The tape is applied to the top surface of the footing to hold in place the wall created from foam panels against wind forces before the concrete coating is applied. The tape should be applied in a staggered manner and in sufficient quantity to provide bonding strength against the wind uplift and over turning loads. Foam wall panels have a foam adhesive applied to their abutting side walls. The adhesive can be sprayed or rolled onto the side walls. Suitable adhesives are 3M TM FASTBOND TM Contact Adhesive 30-NF and 2000-NF. The foam panels are then placed on to the tape on top surface of the footing and into contact with the adhesive on the adjacent panels side wall. After all of the panels are erected to form the walls, the foam panels forming the roof are assembled using the adhesive which joined the wall panels. The foam ribs which reinforce the roof foam panels are pre-cut to the desired shape. The top surfaces of the ribs are joined to the bottom surfaces of the roof panels by the same adhesive used to join foam panels. The adhesive tape used between the footing and the panel is applied to the bottom surface of the ribs. The roof with the reinforcing ribs is lifted on to and bonded to the top surfaces of the walls using the adhesive that joins foam panels together. The interior and exterior surfaces of the instant assembled structure is sprayed with a concrete coating. The concrete coating is then rolled or troweled to the desired finish. The coating can vary from one-eighth inch to several inches depending on the strength requirement

of the area being coated. The coating is applied to the under sides of the roof panels and the sides of the ribs, but the bottom surfaces of the ribs which are adhesive taped are left uncoated. After the coating step, the covering backing on the lower side of the adhesive tape on the ribs is removed. Then the pre-shaped, domed / curved foam ceiling panels/ blocks are lifted into place on to the bottom surface of the ribs. Each ceiling panel is bonded to the next using the foam to foam adhesive (3M FASTBOND TM) to join the side walls of the adjacent panels. The panels can be moved for a time to adjust their alignment before they become immovable. After assembly of the ceiling panels, another coating of concrete is applied starting from the bottom of the interior walls and covering all of the bottom surfaces of the domed / curved ceiling panels. If deemed necessary, the top surface of the ceiling can be coated with concrete. In that case, temporary holes are left within the ceiling to allow spraying of the top surface of the ceiling before the bottom surface of the ceiling is coated with concrete. Then the temporary holes are filled with ceiling panels or portions of panels, and the ceiling bottom side is coated with concrete. The final thickness of the concrete coating is a function of the desired strength and the degree of fire protection required. A three-eighths inch coating thickness can provide a fire rating of more than one hour. The interior and exterior concrete coatings can receive various types decorative coatings, such as cement base coatings, paint, etc..

Some of the concrete coatings can be applied without the reinforcement obtained from using glass fibers. Some areas of the foam walls may be coated with multiple coatings or layers. For example, a first layer would have no fibers, a second layer would contain glass fibers and a third layer would contain no fibers.

Where there is a joining of two existing layers (a "cold joint"), a reinforcing mesh is placed over the joint area of the layers. The mesh is formed in a screen or lattice like pattern. The rectangles of the pattern can be one centimeter on each side. The mesh is formed from glass fiber bundles (700-1,000 fibers) that are covered with a

protective sheath of polyvinyl chloride. The joint with the overlying mesh is then coated with concrete to form the joining coating or layer.

The GFRC coating uses glass fibers which are resistant to the alkali found in concrete. The fibers have a diameter of between 13.5 and 20 + or - 2 microns, a length of between 0.25 and 1.50 inches and a roving tex of 200 yards per pound + or – 10%. They have a minimum of 16% zirconia and a density of 2.7 grams per cubic centimeter. The cement is Portland cement. A typical premix formulation is 100 pounds of cement, 75 pounds of sand, 29 pounds of water, 16 ounces of super plasticizer, 10.6 to 12.6 pounds of polymer and 6.5 to 9 pounds of chopped 0.50 inch glass fiber. Further information can be provided by the PRECAST / PRESTRESSED CONCRETE INSTITUTE of Chicago, Illinois.

Suitable adhesives used to join foam to foam are 3M TM FASTBOND TM Adhesive 30 – NF and 2000 – NF or SUPER 77 Spray Adhesive. A suitable adhesive to join foam to concrete is 3M TM VHB TM Double Coated Acrylic Tape 4910. This tape is an acrylic closed cell tape having a protective covering layer or backing on both sides that is removed to apply the tape. The tape can be applied using a SCOTCH TM AT 6700 applicator.

The core material can be any light weight material which has sufficient strength, such as, plastic foams, bonded wood chips, etc.. Preferably, the core material is EPS (expanded polystyrene) foam panels which are one to four pounds per cubic foot in density. Where the foam is to receive adhesive, 5 – 20 % regrind is present in the foam for better adhesion.

The roof can be formed of eight inches of virgin (100%) EPS foam with three sixteenths inches of GFRC coating on the top and the bottom surfaces. An elastomeric acrylic latex coating (FUTURA BASF ACRO-BOND TM 448) is applied to the outside GFRC coating to form an elastic membrane to seal the

concrete coating against moisture and rain penetration to the interior of the roof. The roof foam can have other foam panels that have been shaped to resemble a group of shingles, Spanish style tiles or other roof material adhered to the top surface of the roof foam. The shaped foam panels are coated with the concrete coating and then the elastomeric sealing coating.

The GFRC coating on the sides of the ribs and on the bottom surface of the roof forms reinforcing or stiffening members for the roof.

CAD programs are available as AutoCad TM, ProE TM, Solid Works TM, Inventor TM, etc. CAM programs are available as Fast CAM TM, etc.

The habitable building is formed of a mixture of curved 40 and straight walls 42. The curved ceiling (dome) 40 together with ribs 42A performs the function of rafters and trusses in conventional houses. The ribs 42A on the top surface of the ceiling 40 supports the roof 45 which in the previous embodiment is planar or plate-like and thus needs support.

A building constructed according to this invention using composite structures formed from EPS foam and GFRC has been analyzed by computer modeling. The building has been found to be resistant to extreme wind, snow and earthquake forces (magnitude IV California area) and passes the U.S. Building Code.

Some of the curvatures have been exaggerated from what would be the usual curvature so the curvature of the elements will be more apparent.

Various changes and modifications to the embodiments herein chosen for purposes of illustration will readily occur to those skilled in the art. For example, the order of the steps required to build the house can be changed. The number of steps required to build the house may be varied. The number of coats of concrete and the

composition of those coats can be varied. The specific materials used to build the house or the curved structure may be varied, such as the type of foam, adhesives, plastic, etc.. To the extent that such modifications and variations do not depart from the spirit of the invention, they are intended to be included within the scope thereof which is assessed only by a fair interpretation of the following claims.

Industrial Applicability

The present invention is capable of being exploited in the building industry. One embodiment is particularly appropriate for use in mall construction. The other embodiment is particularly appropriate for use in housing construction. Utilization of the present invention can substantially reduce the costs of constructing malls and houses.

Claims

Claim 1 The method of providing a composite curved structure as part of a habitable building comprising the steps of,
creating a drawing of the curved structure, said curved structure having sides and a top surface,
forming the top edge of the sides to match the curvature of the curved structure thereby creating a curved top edge,
forming the top surface from a flat panel,
joining the sides and the top surface together to form the composite curved structure by
joining the sides to each other,
placing the top panel on the curved edges of the sides,
then bending the top panel on to the curved edges of the sides and
joining the top panel to the curved edges of the sides.

Claim 2 The method of claim 1 wherein,
the step of creating the drawing is performed with the aid of a computer by using a computer assisted drafting program.

Claim 3 The method of claim 2 wherein,
the steps of forming are performed by a computer assisted cutting machine that receives data from the computer assisted drafting program to guide the machine in forming steps.

Claim 4 The method of claim 1 wherein,
the drawing of the structure divides the total structure into sections,
each section is assembled and
the sections are then joined to from the total structure.

Claim 5 The method of claim 4 wherein,
the sections are created from multi-sided forms.

Claim 6 The method of claim 1 including the steps of,
forming the bottom edge of the sides to match the curvature of the curved structure thereby creating a curved bottom edge,
forming the bottom surface from a flat panel,
joining the sides and the bottom surface together to form the composite curved structure by
joining the sides to each other,
placing the bottom panel on the curved edges of the sides,
then bending the bottom panel on to the curved edges of the sides and
joining the bottom panel to the curved edges of the sides.

Claim 7 The method of providing a composite curved structure as part of a habitable building comprising the steps of,
creating a drawing of the curved structure, said structure having a curved bottom surface,
dividing the drawing of the curved structure into sections,
forming the sections from a core material,
forming the curvature of the bottom surface of the structure in the bottom surface of the core material,
joining the sections to form the curved structure, and
coating the curved bottom surface of the structure with a material that hardens into a strong layer.

Claim 8 The method of claim 7 wherein,
the step of creating the drawing is performed with the aid of a computer by using a computer assisted drafting program.

Claim 9 The method of claim 8 wherein,
the steps of forming are performed by a computer assisted cutting machine that receives data from the computer assisted drafting program to guide the machine in forming steps.

Claim 10 The method of claim 7 wherein,
the sections are created from multi-sided forms.

Claim 11 The method of claim 7 including the steps of,
forming the curvature of the top surface of the curved structure in the top surface of the core material and
coating the top surface of the structure with a material that hardens into a strong layer.

Claim 12 The method of claim 7 including the step of,
forming the curvature of the top surface of the curved structure in the top surface of the core material,
forming ribs of a core material to match the curvature of the top surface of the structure,
joining the ribs to the top surface of the structure and
coating the curved top surface of the structure and the ribs with a material that hardens into a strong layer.

Claim 13 The method of claim 7 wherein,
the core material is expanded polystyrene foam and
the coating is glass fiber reinforced concrete.

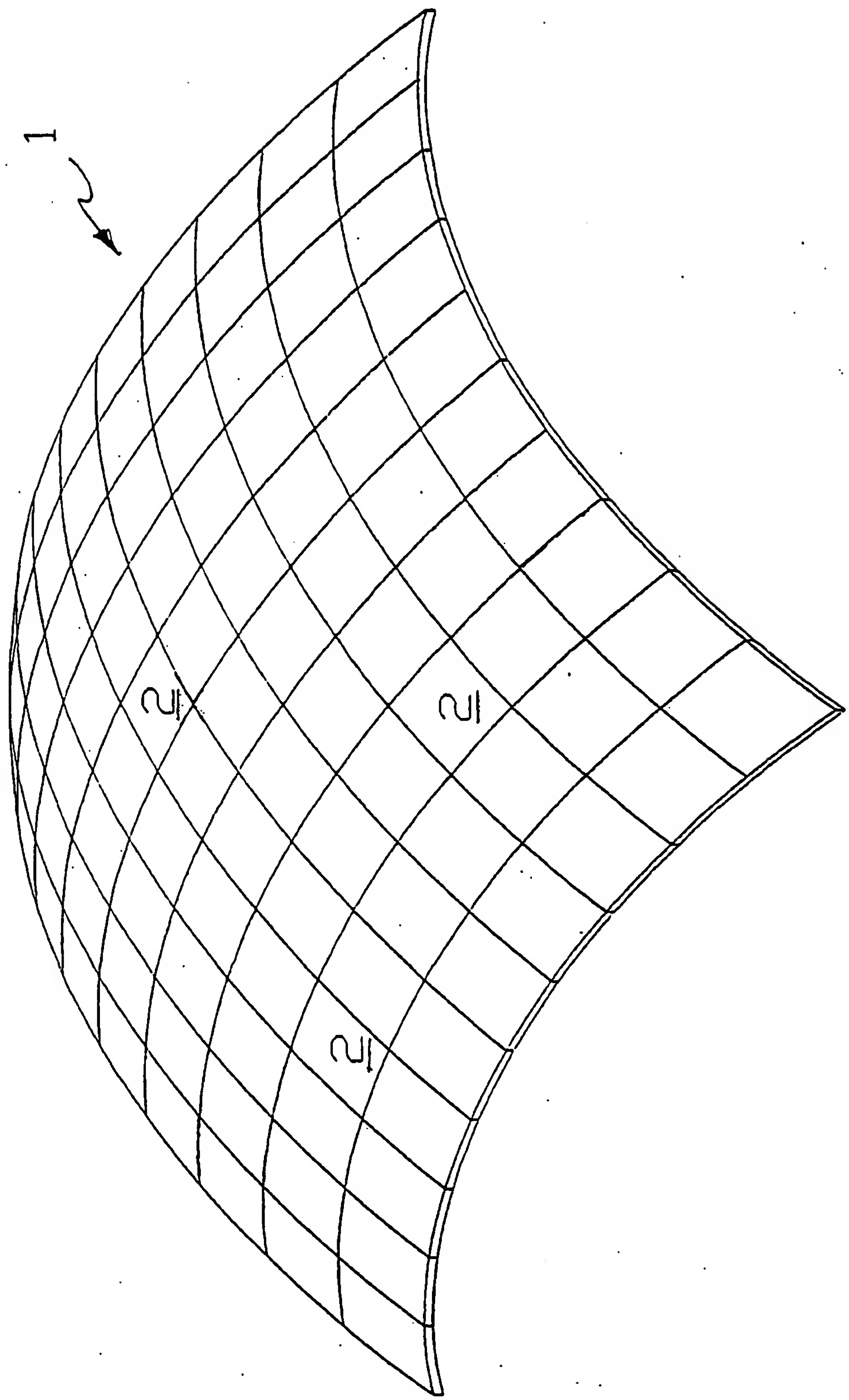


Fig. 1

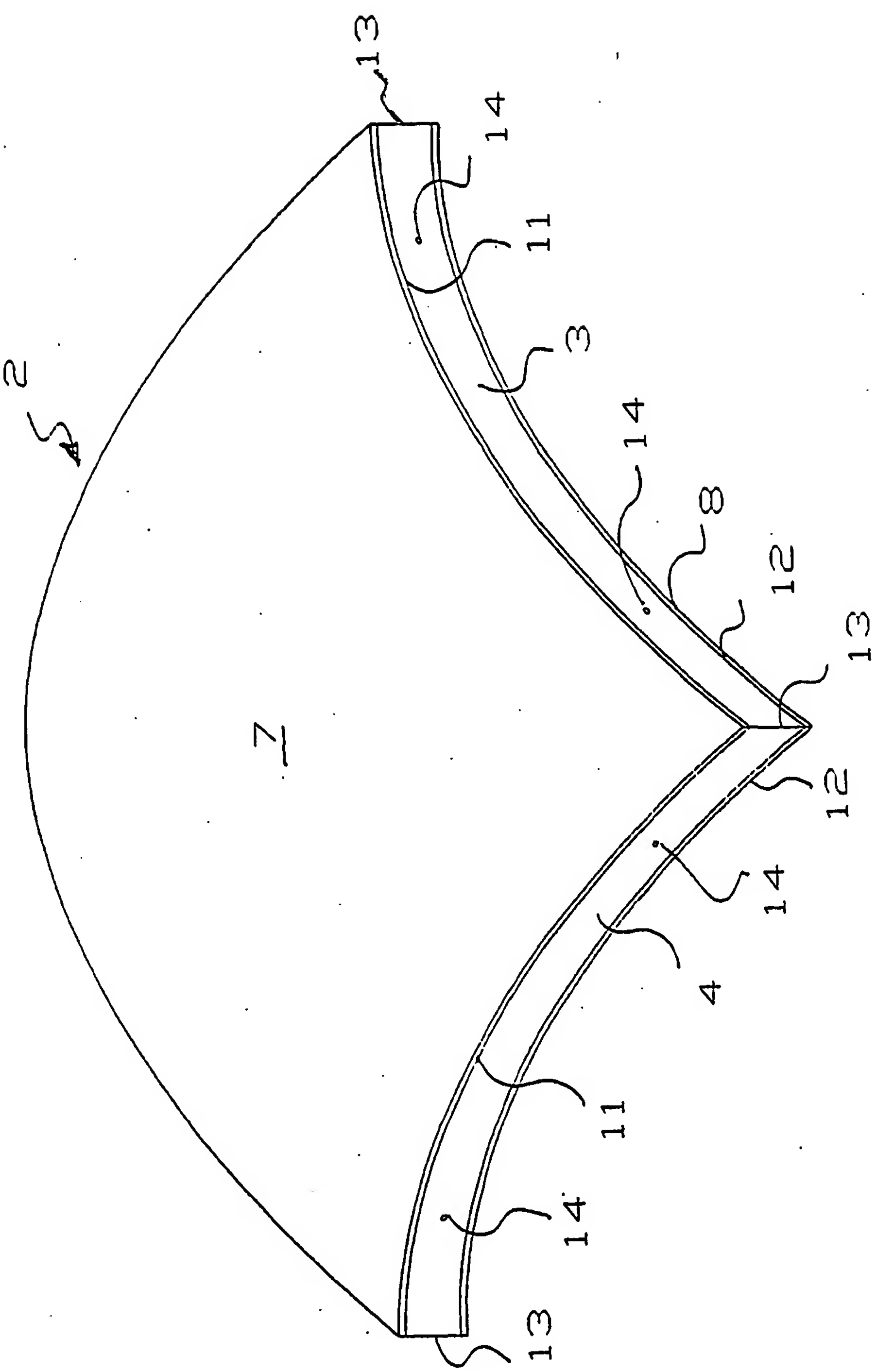


Fig. 2

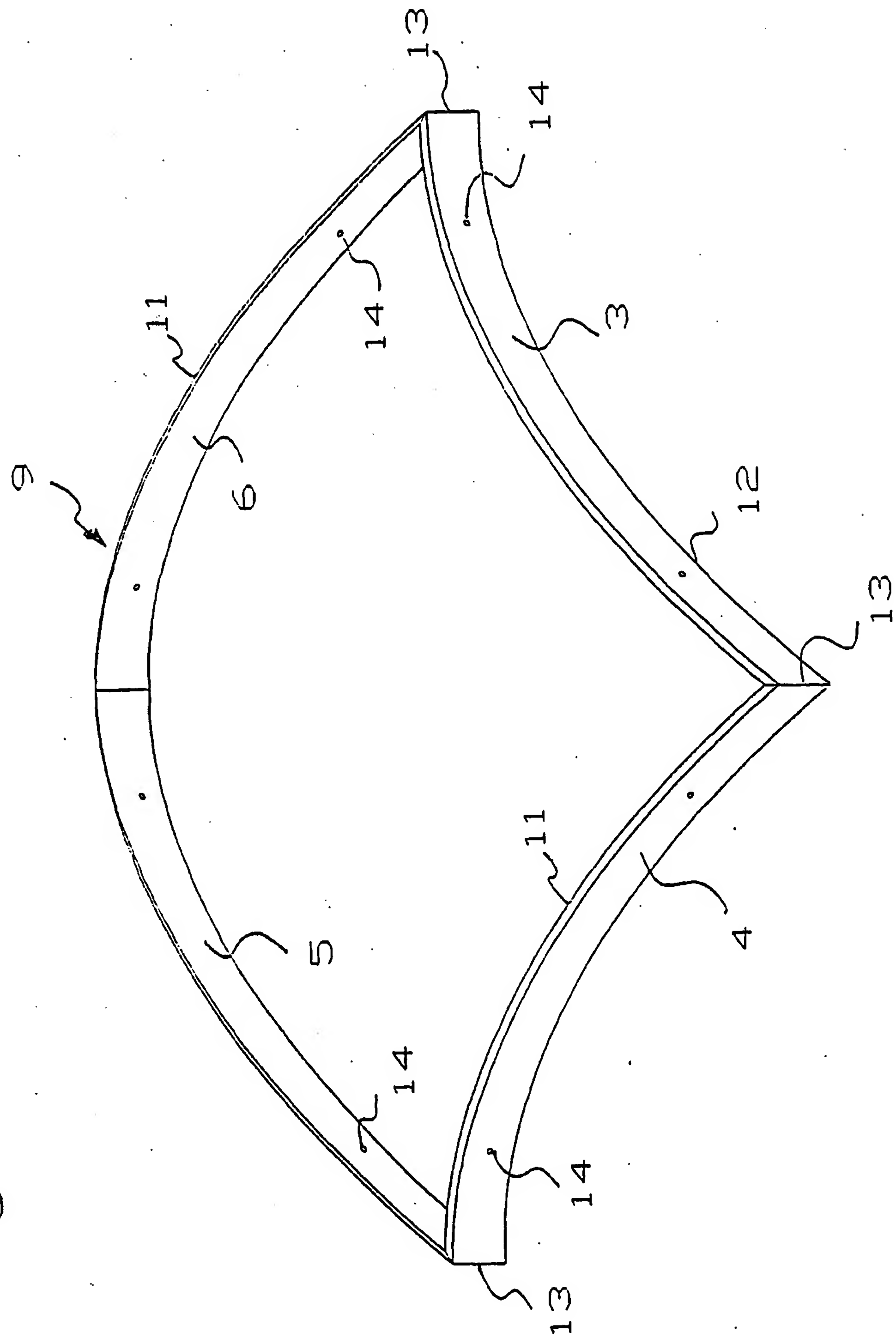


Fig. 3

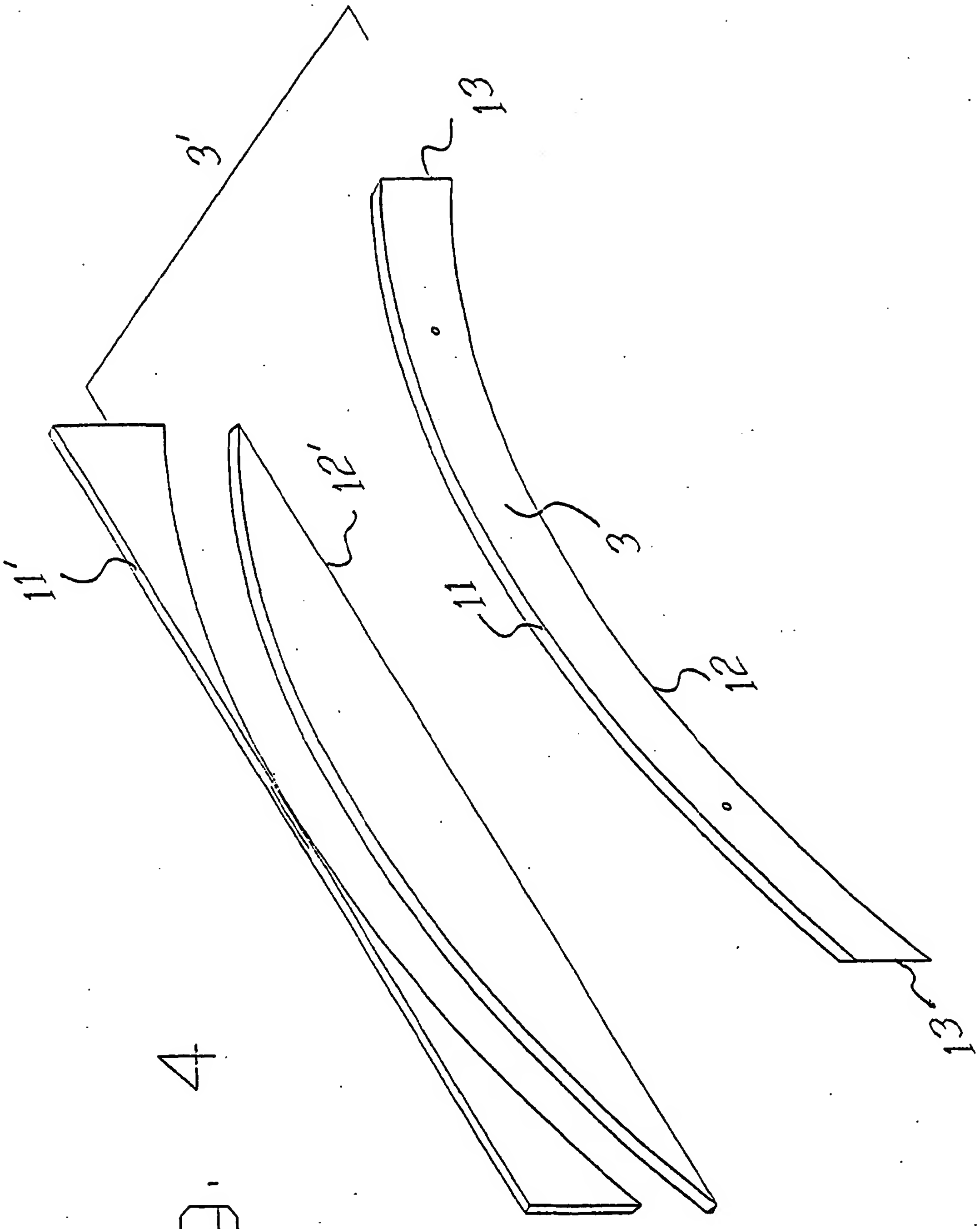


Fig. 4

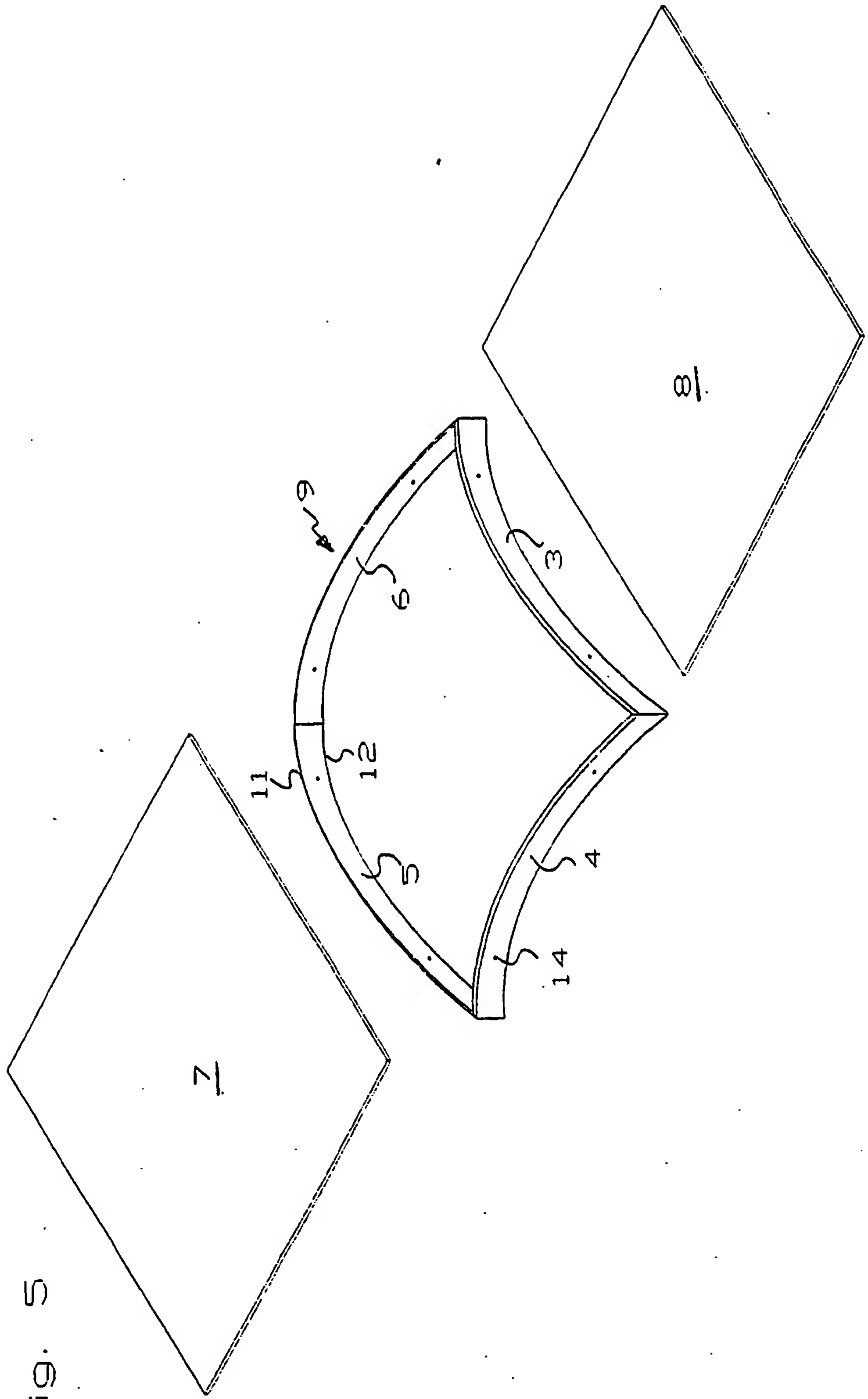


Fig. 5

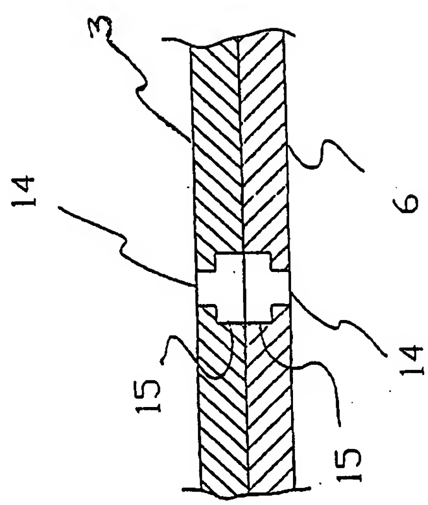


Fig 6

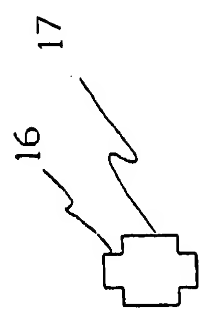


Fig 7

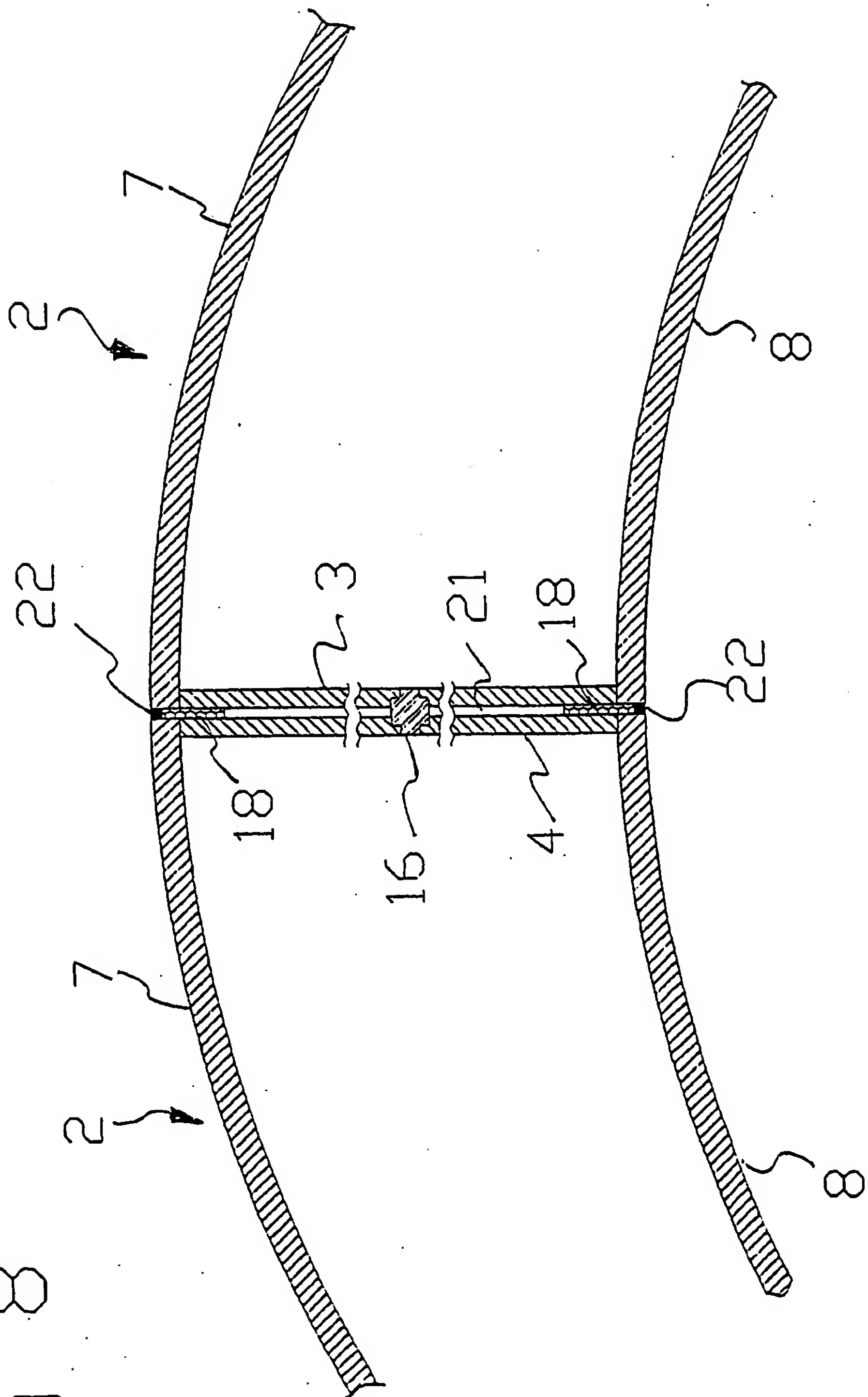


Fig 8

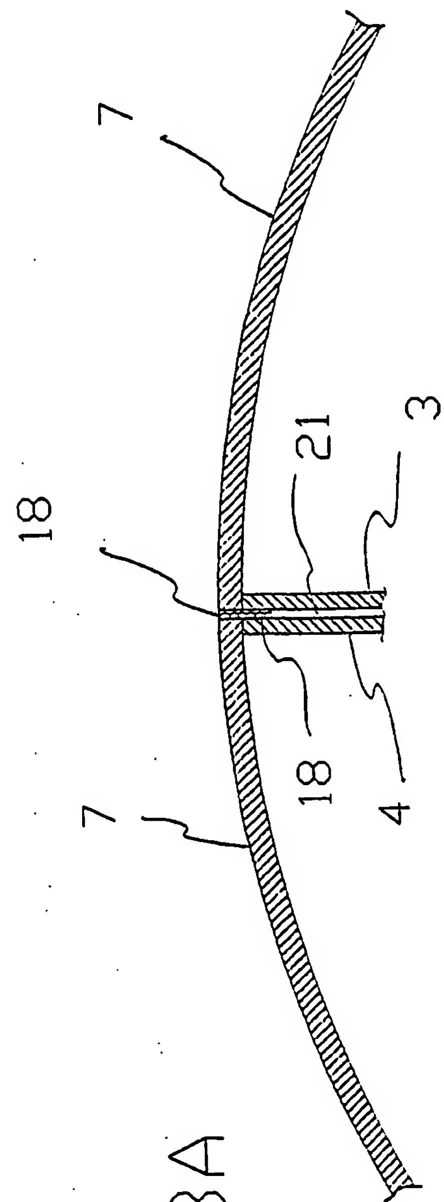


Fig 8A

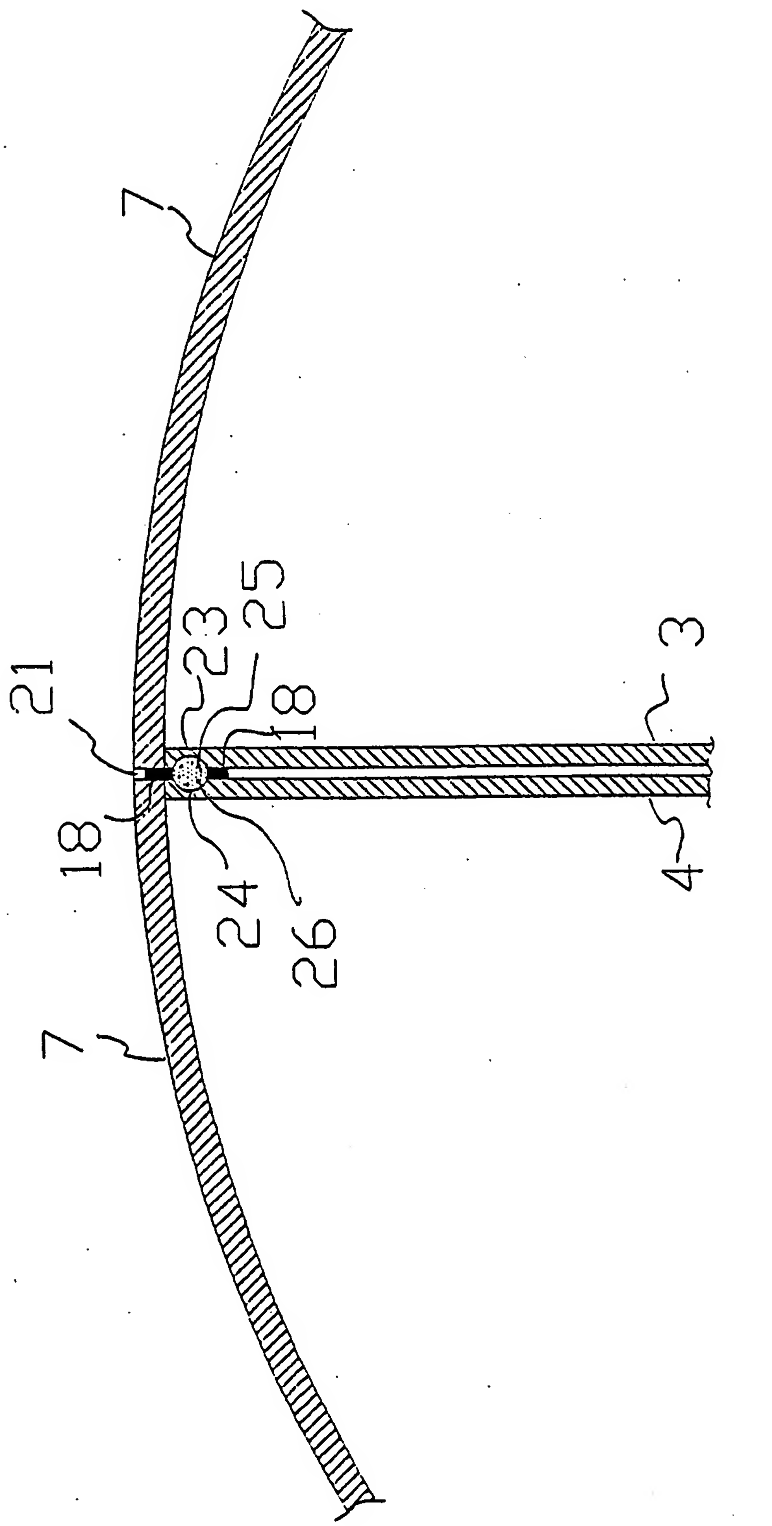


Fig 9

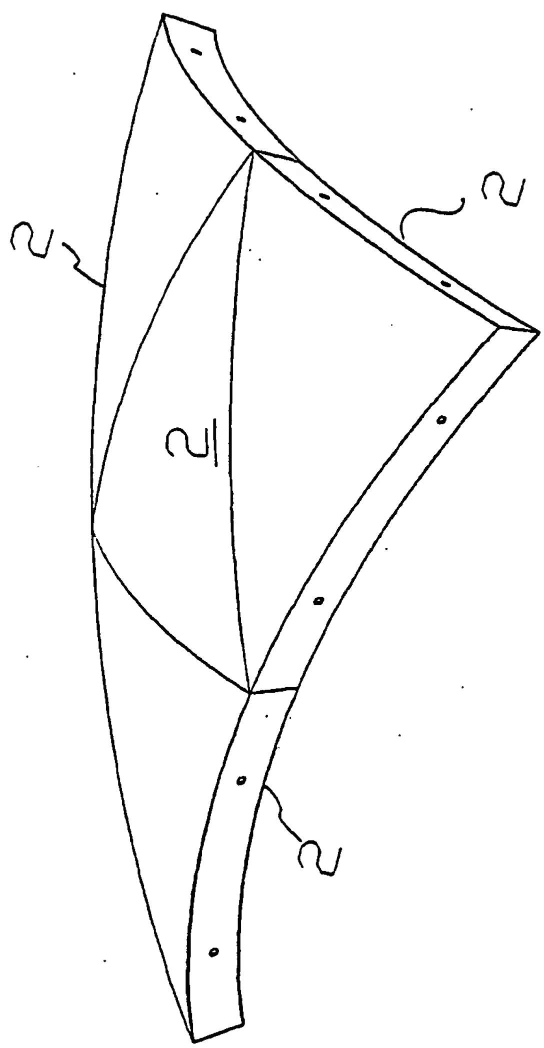
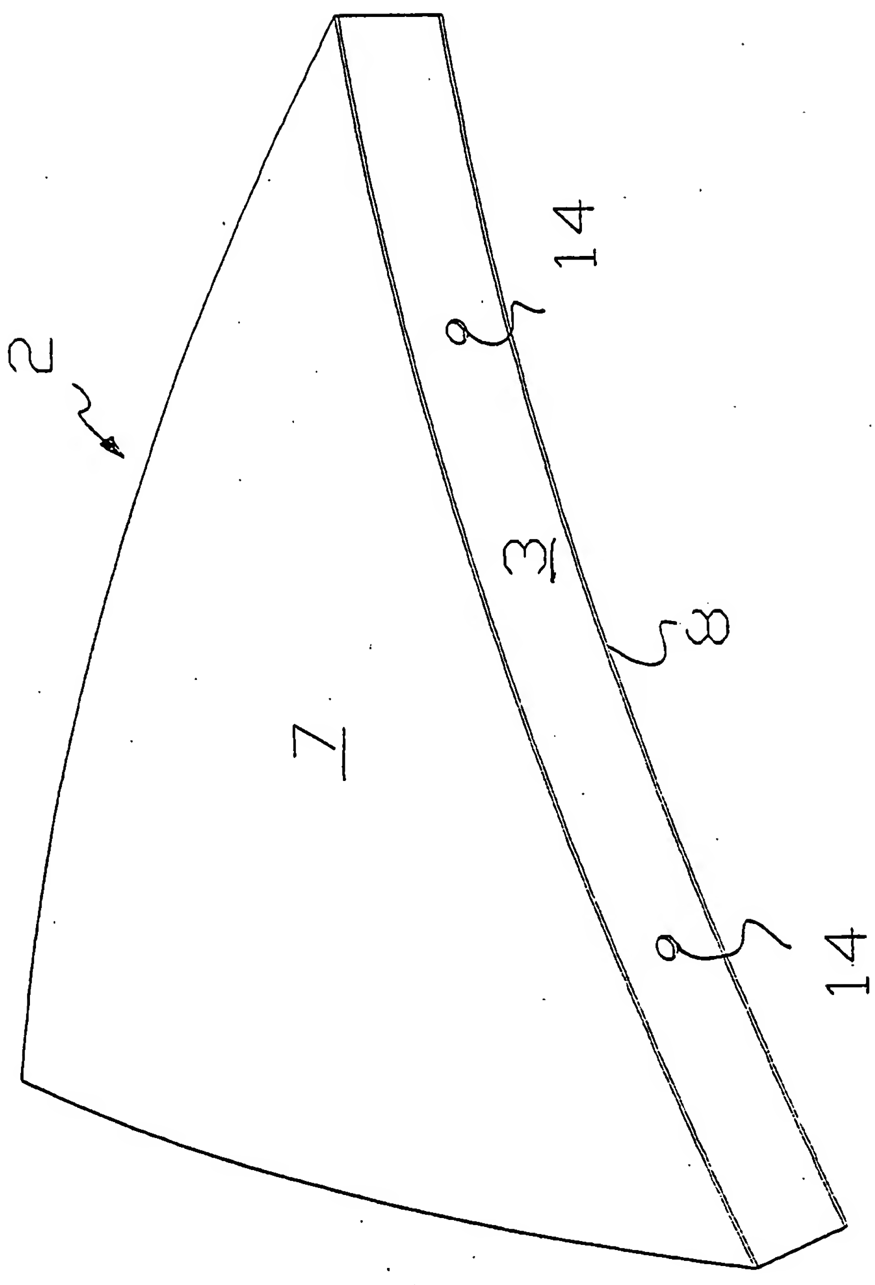


Fig. 10

Fig. 11



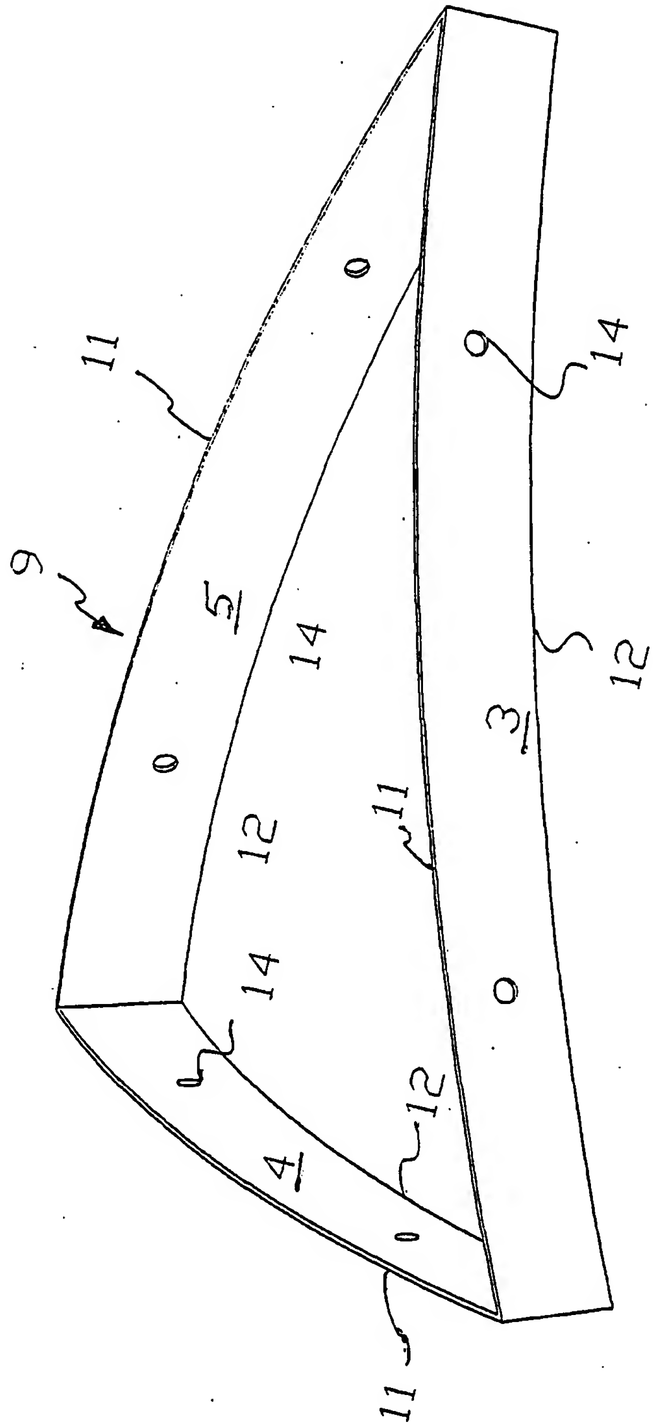


Fig. 11A

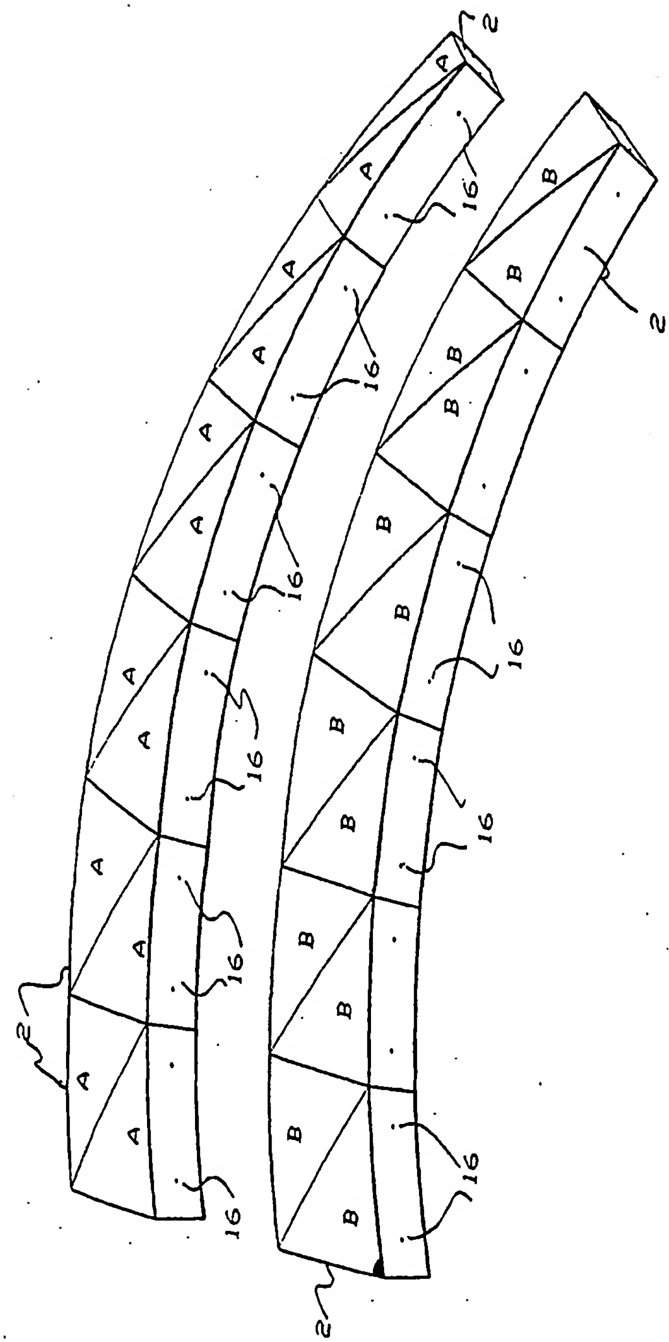


Fig 12

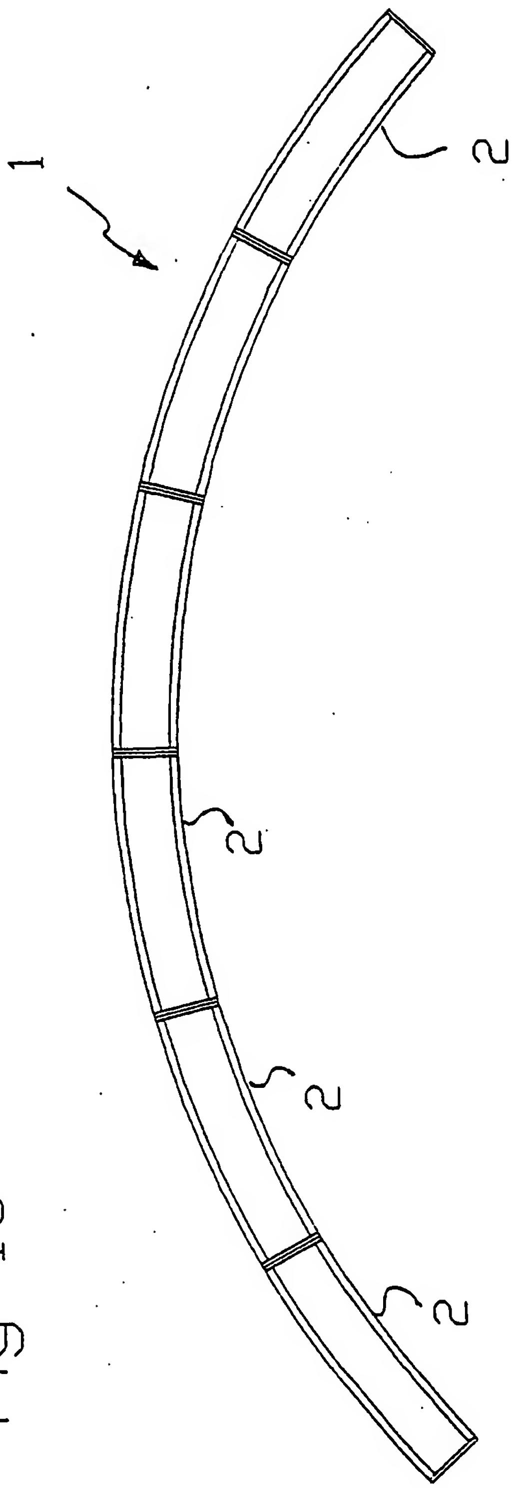


Fig 13

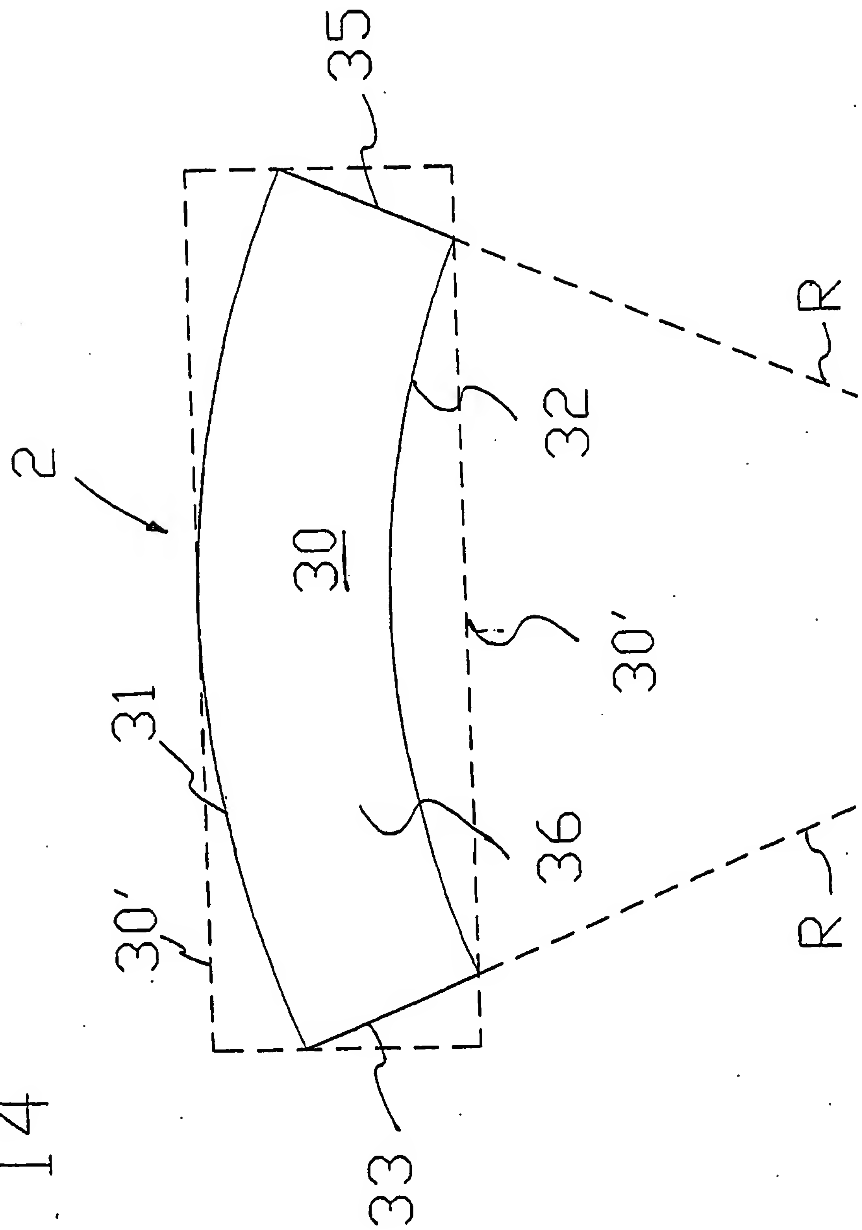


Fig. 14

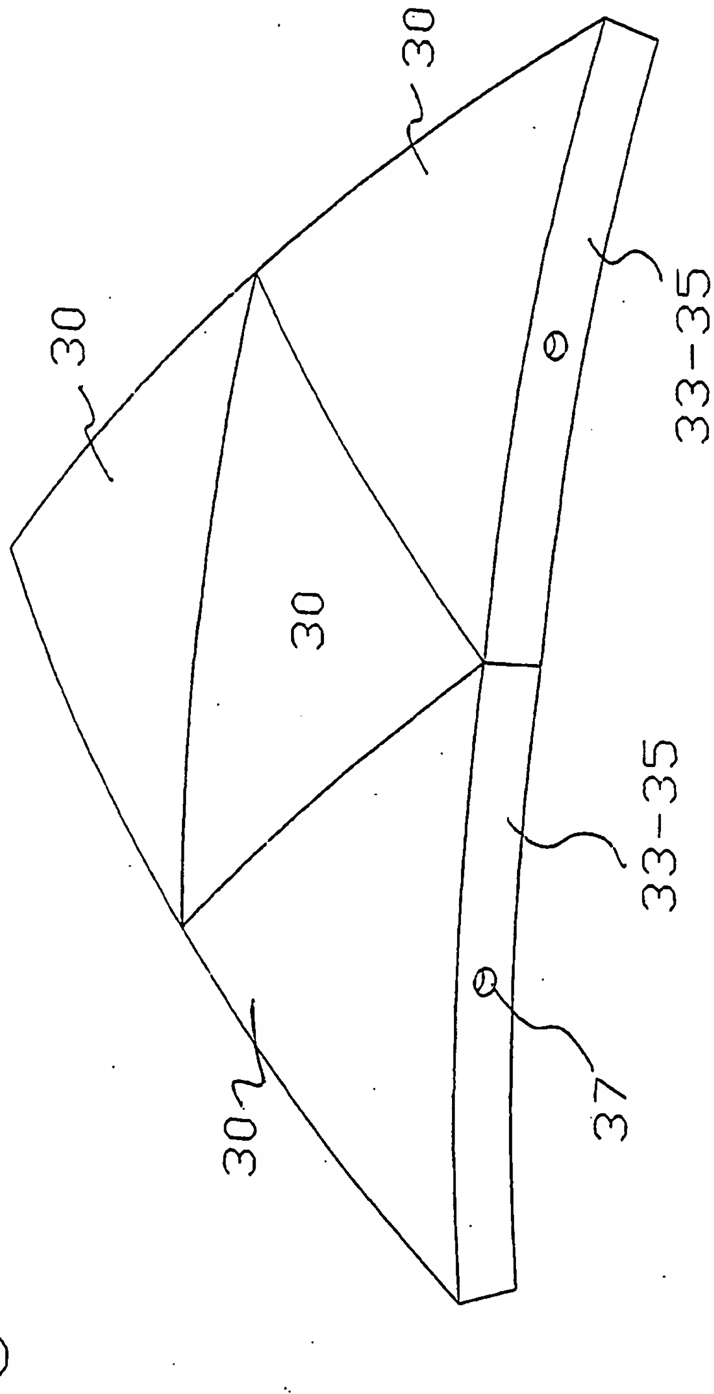


Fig. 14A

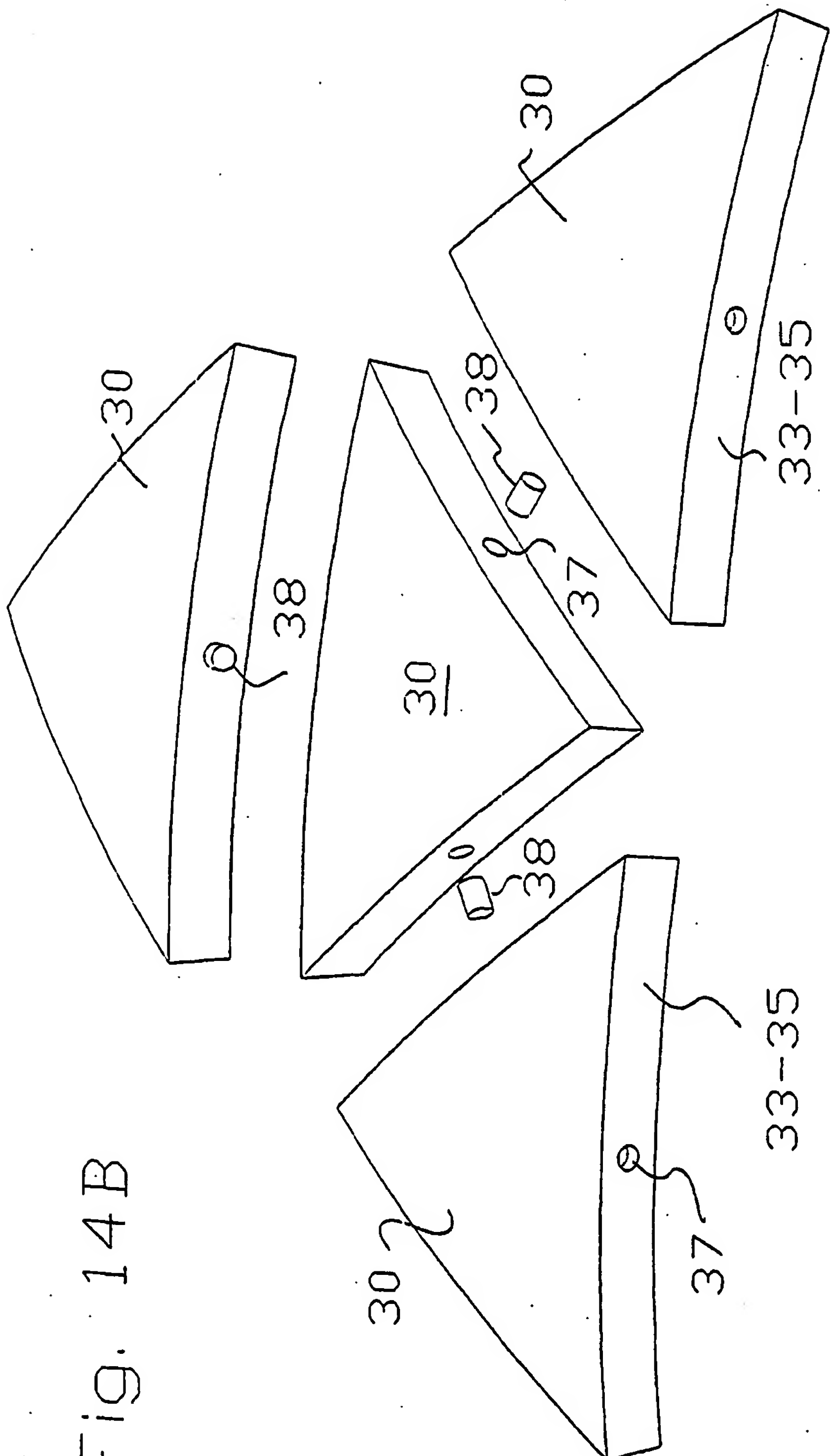


Fig. 14B

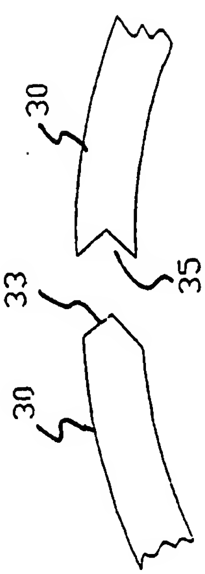


Fig. 15A

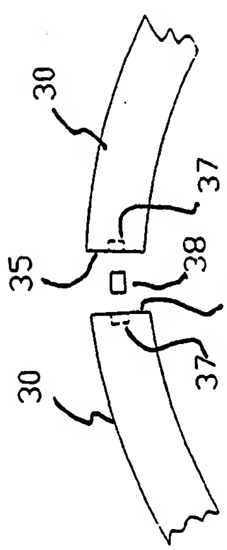


Fig. 15A

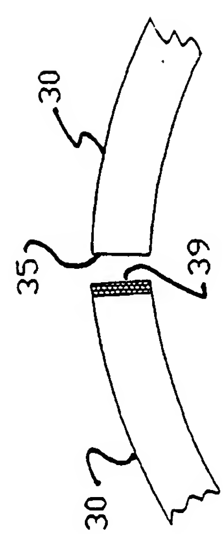


Fig. 15C

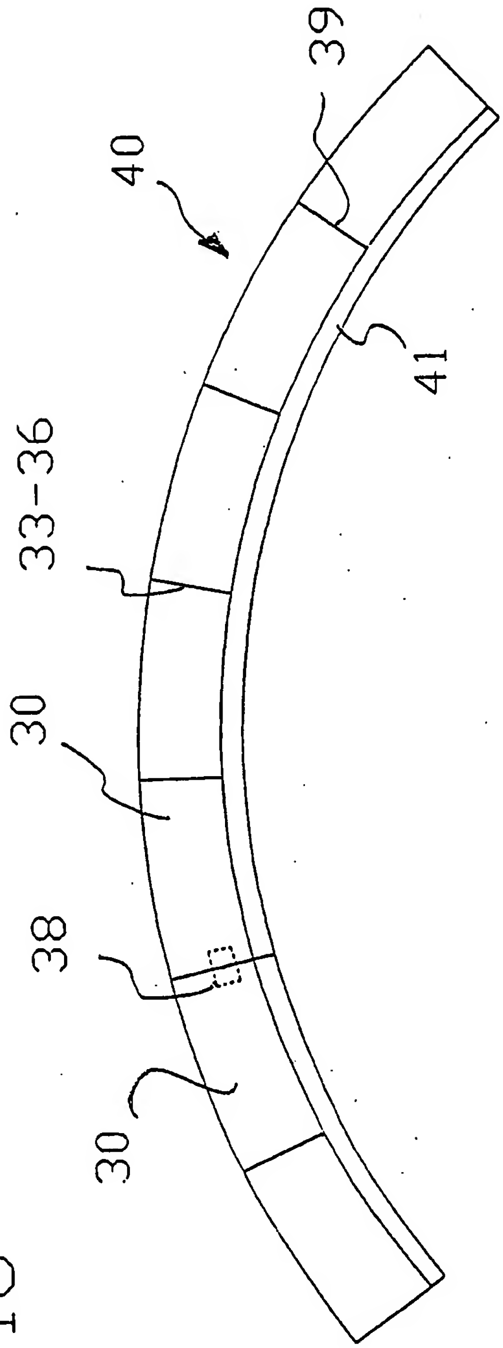


Fig. 16

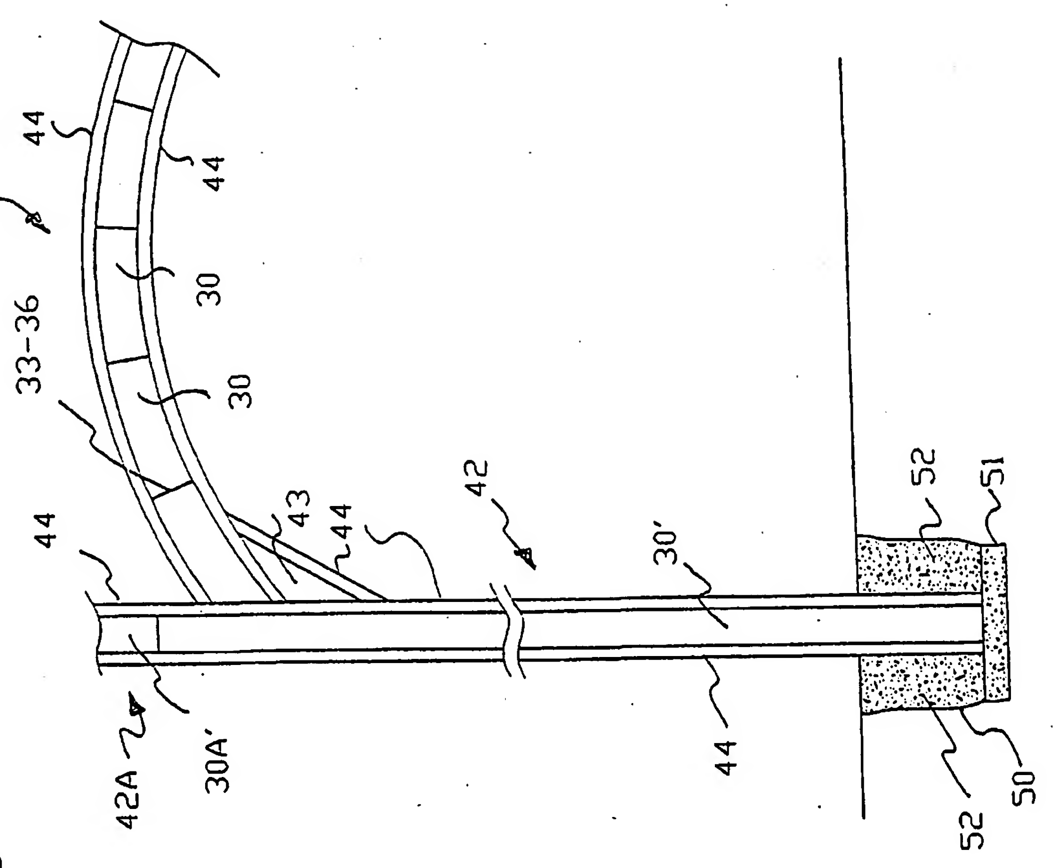


Fig. 17

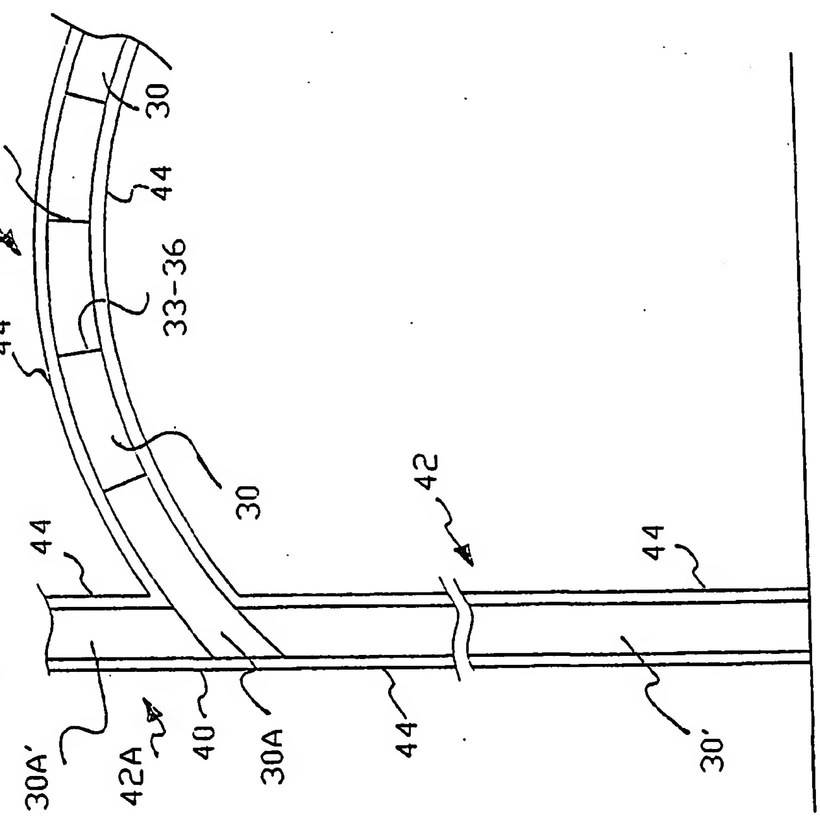


Fig. 17A

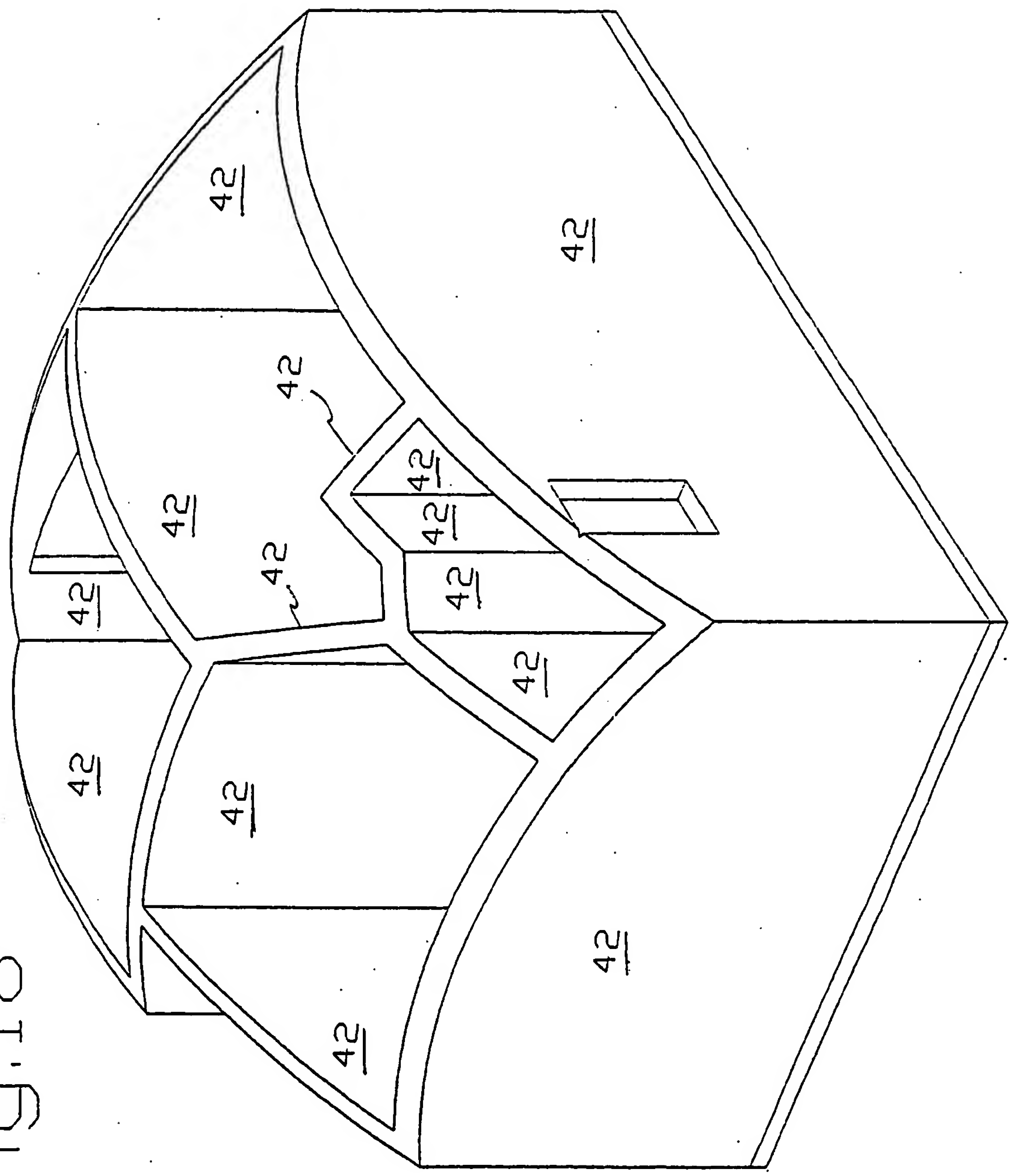


Fig.18

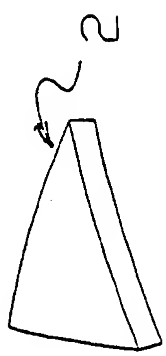


Fig.19A

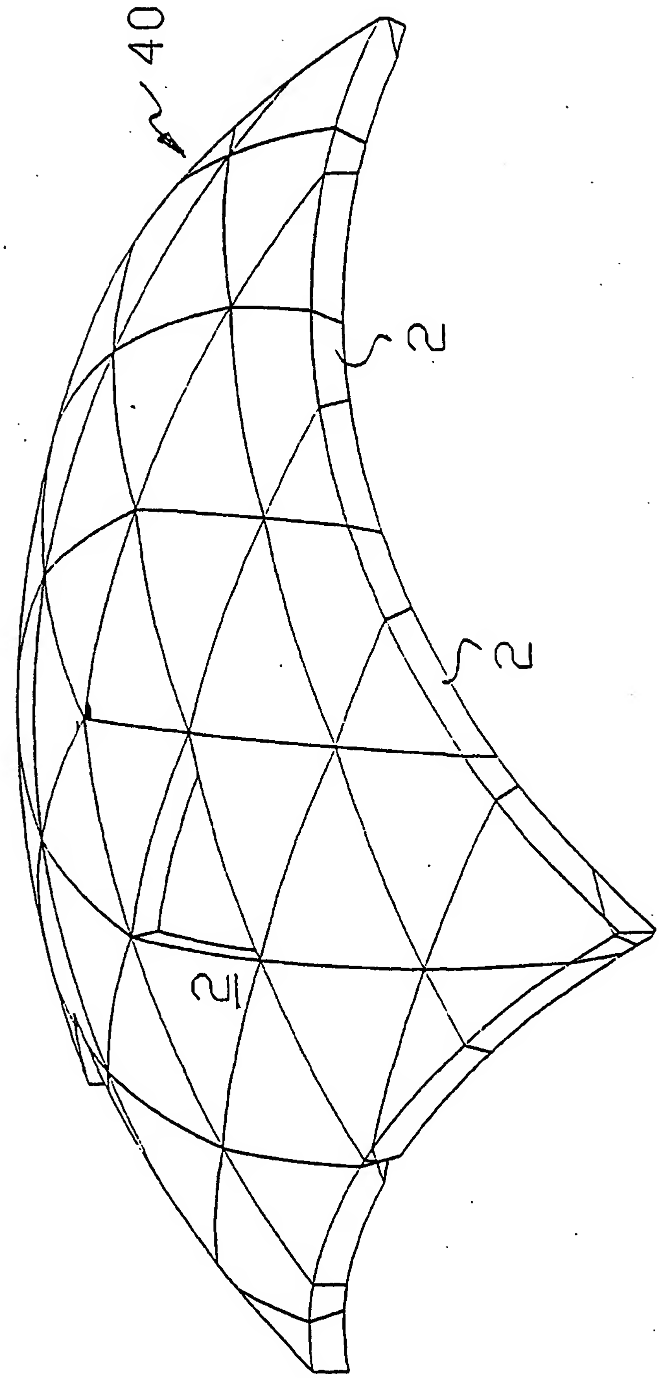


Fig.19

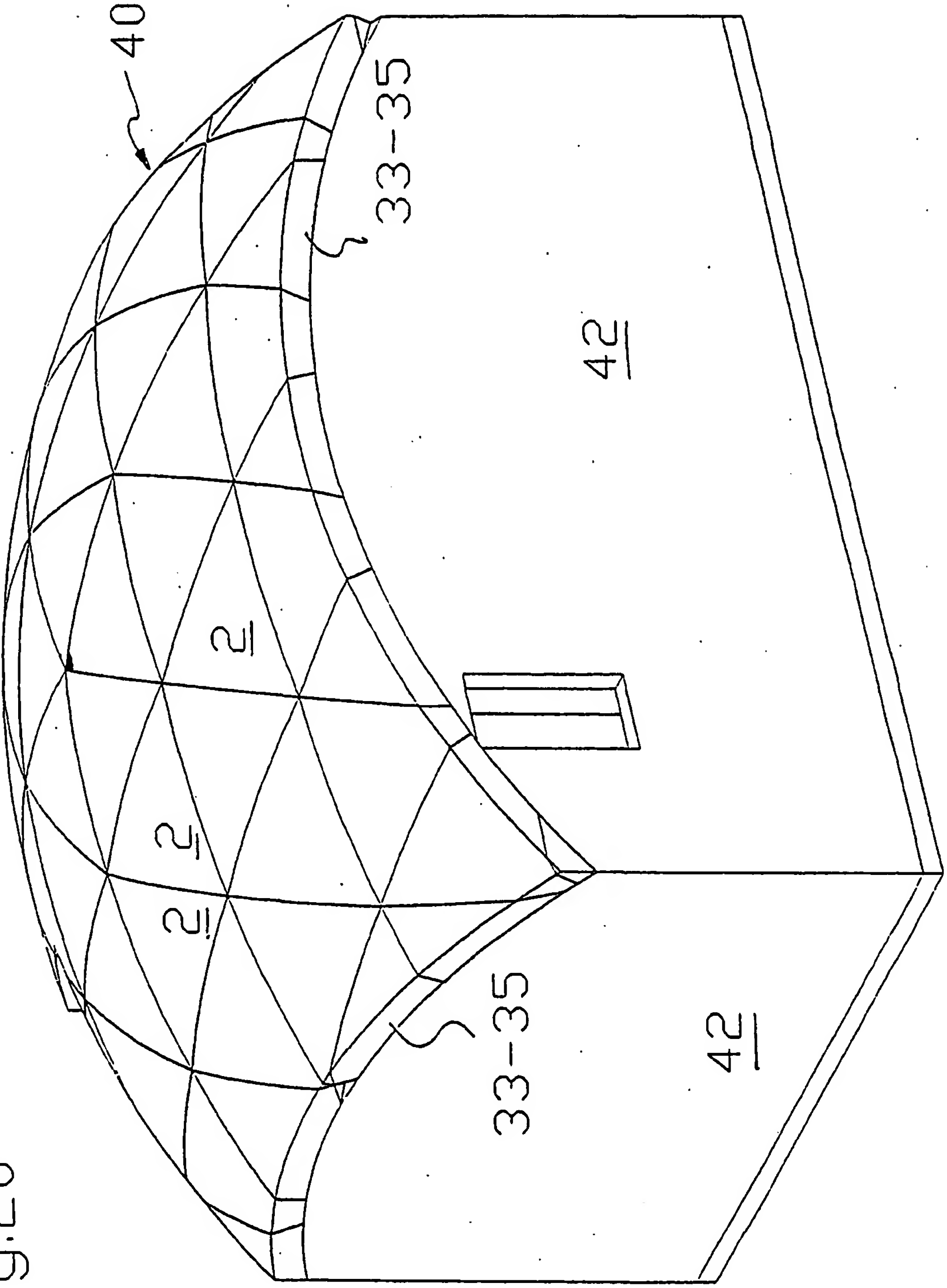


Fig.20

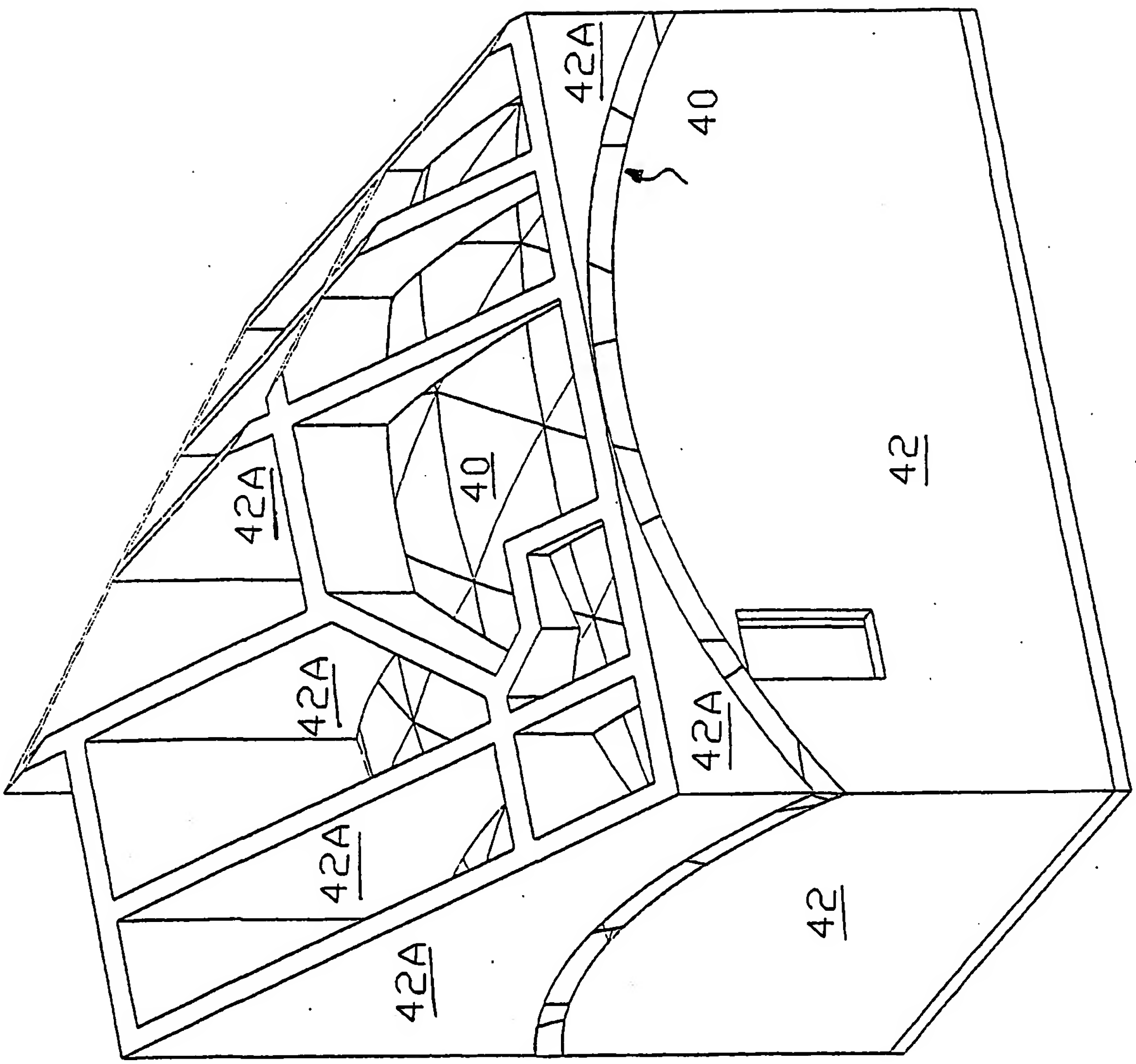


Fig.21

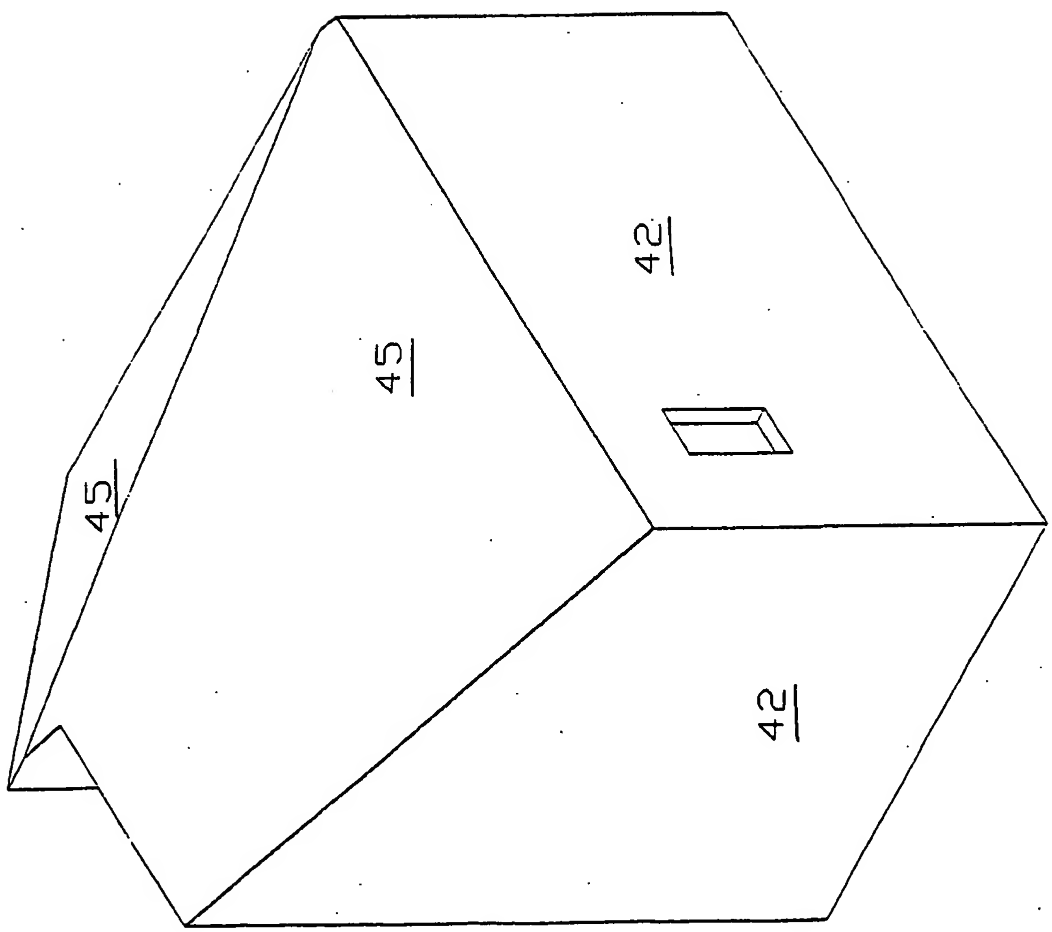


Fig.22

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/42302

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : B21D 47/00
US CL :29/897.32
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : Please See Extra Sheet.

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EAST TEXT SEARCH

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4,068,422 A *(SUMNER)* 17 January 1978, See the instant Specification.	1, 4-6
Y	US 4,557,090 A *(KELLER. SR.)* 10 December 1985, See the instant Specification.	1, 4-6
Y	US 6,094,877 A *(WHITE)* 01 August 2000, See the instant Specification.	1, 4-6
Y	US 5,816,013 A *(OPFERBECK et al.)* 09 October 1998, See the instant Specification.	1, 4-6
Y	US 4,077,177 A *(BOOTHROYD et al.)* 07 March 1978, See the instant Specification.	7, 10, 11
Y	US 4,671,035 A *(RIDGE)* 09 June 1987, See the instant Specification.	7, 10, 11

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
29 APRIL 2001	28 JUN 2001

Name and mailing address of the ISA/US	Authorized officer
Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	IRENE CUDA-ROSENBAUM Sheila Veney Paralegal Specialist Technology Center 3700
Facsimile No. (703) 305-3230	Telephone No. (703) 308-1792

Form PCT/ISA/210 (second sheet) (July 1998)★

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4,808,246 A *(ALBRECHT et al.)* 28 February 1989, See the instant Specification.	7, 10, 11
Y	US 5,581,960 A *(LEWIS)* 10 December 1996, See the instant Specification.	7, 10, 11
X	US 4,785,605 A *(JENN)* 22 November 1988, See the instant Specification.	7, 10, 11
Y	US 4,178,820 A *(GERBER)* 18 December 1979, See the instant Specification.	2, 3, 8, 9

B. FIELDS SEARCHED
Minimum documentation searched
Classification System: U.S.

29/897.32, 897.3, 897.312, 446, 448, 449, 458, 460;
52/745.07, 745.19, 745.20, 86, 88, 81.4, 81.2;
83/13.